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**Forest Pest
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**Methods
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Fort Collins,
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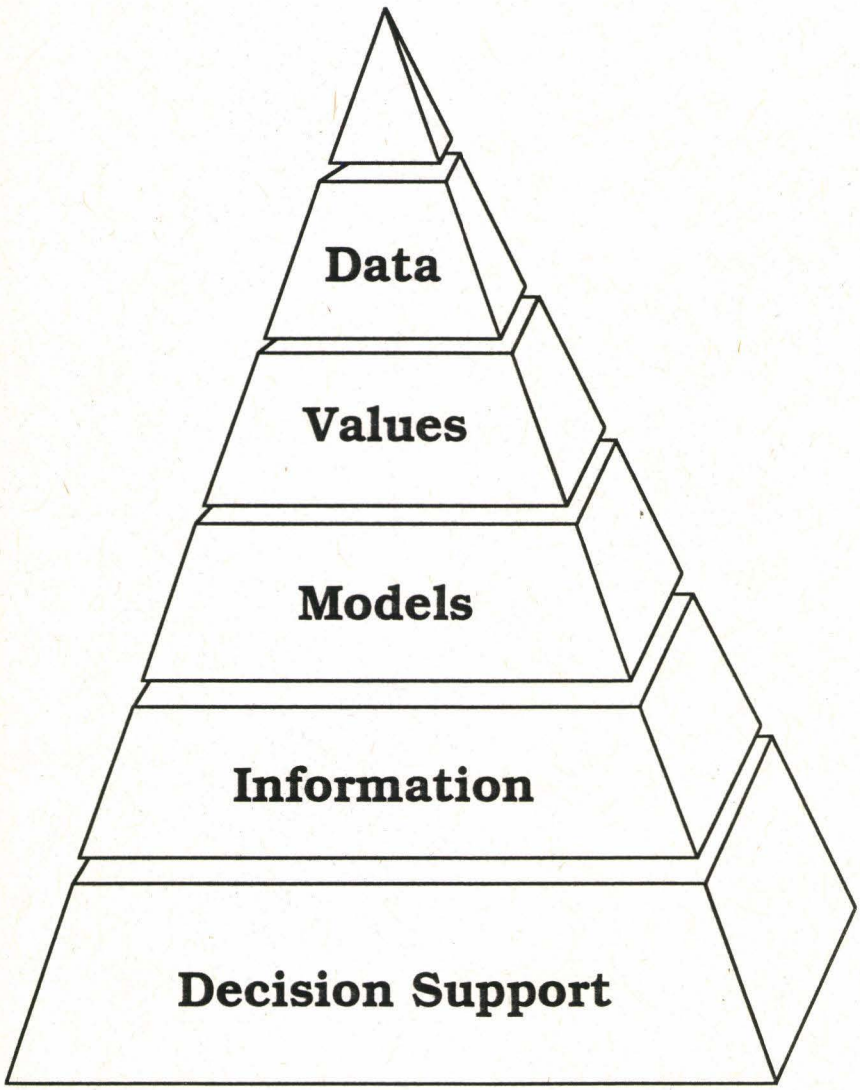
Forest Health Technology 2000

Task Force Report



Forest Health Technology 2000
Task Force Report

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Overview

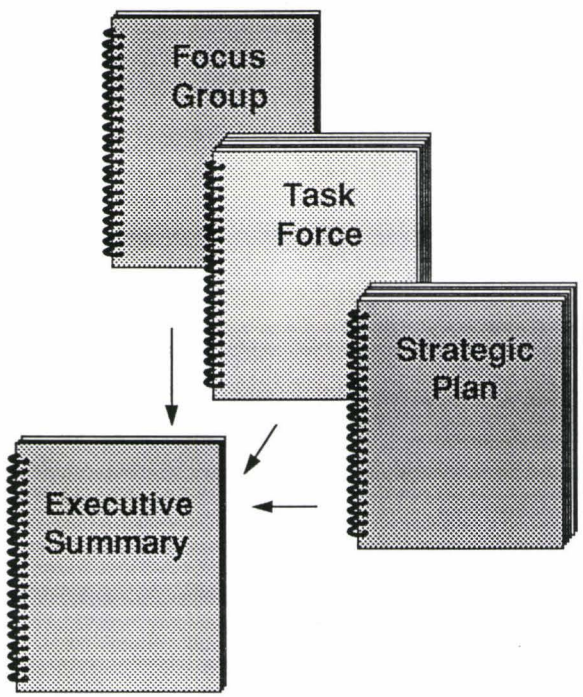
Forest Health Technology 2000 is a strategic planning process. The goal of the process is to identify challenges to forest health in the 21st Century and to ensure the availability of appropriate ecosystem management technologies to help meet those challenges. There are three principal components of this process:

The **National Forest Health Challenges Focus Group** identified six major forest health challenges, and suggested emerging technologies appropriate to address those challenges;

The **Forest Health Technology Task Force** developed more detailed concept plans for the adaptation, development, testing, and implementation of technological systems appropriate to five of the identified challenge areas; and

The **Methods Applications Group Strategic Plan** presents a more refined strategic plan for the accomplishment of those technology development and implementation activities suited to the mission and capabilities of FPM/MAG and its contractors and cooperators.

The results of Forest Health Technology 2000 are documented in three coordinated reports (cited herein) and are summarized in the *Forest Health Technology 2000 Executive Summary*.



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Abstract

This Task Force report presents the collective ideas of over sixty scientists, resource technology developers, and users who gathered to develop a strategy for making appropriate technology available to meet emerging forest health challenges in the year 2000 and beyond. The **Forest Health Technology Task Force** is part of a multi-step process, *Forest Health Technology 2000*, undertaken by the USDA Forest Service, Forest Pest Management, Methods Application Group. This strategic planning process began with the **National Forest Health Challenges Focus Group**, a group of scientists, technology developers, environmental managers, and policy makers. The focus group identified six major challenges to forest health for the 21st Century, and suggested appropriate technologies to address those challenges. The **Forest Health Technology Task Force** continued the strategic planning process by developing more detailed conceptual plans for developing, testing, and implementing technological systems for five of the identied forest health challenge areas. This report presents those five technology development plans.

Acknowledgements

The staff of the Methods Application Group would like to express their sincere gratitude to the members of the Task Force, who gave freely of their time, knowledge, and commitment to developing a strategy for making appropriate technology available to address forest health challenges of the 21st century.

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1.0 Introduction

1.1 Background

The Forest Health Technology Task Force was convened in Las Vegas, NV from March 29 to 31, 1994. The charge to the 60 member Task Force was to develop conceptual plans for the development and delivery of technological systems needed to support forest ecosystem management in the 21st Century. Five separate technology areas, previously identified by the National Forest Health Challenges Focus Group (Daniel et al. 1994), were addressed: *value determination*, *data and information needs*, *analysis and modeling*, *information display*, and *decision support systems*. The results of the Task Force's efforts are presented in the following report.

A broad cross section of forest ecosystem scientists, technology developers, and technology users/customers were represented on the Task Force. Participants were recruited from Forest Pest Management field units and from Regional and National Forest staffs. In addition, there were representatives of the Methods Application Group (MAG) staff, contractors, and university cooperators, as well as representatives of other Forest Service units which are important current and potential future partners in ecosystem management technology development, including Research, Information Systems and Technology, and Ecosystems Management.

The Task Force was divided into five groups, each addressing one of the five technology need areas. Each group was headed by an individual with substantial background in the respective technological areas. ESSA Technologies Ltd. served as the meeting facilitators.

The stated scope for the Task Force effort was intentionally very broad, not restricted to the Methods Application Group, to Forest Pest Management, or even to the Forest Service as a whole. Instead, the domain encompassed as much as possible of the full array of technological systems and tools needed to support "forest ecosystem management". The process began with a general introduction to and group discussion of the concepts and issues relevant to ecosystem management (Kaufmann et al., 1994). No effort was made to press for firm conclusions, final definitions, or overall group consensus on the future implications of ecosystem management.

With the National Forest Health Challenges Focus Group report and the introduction to forest ecosystem management as background, the Task Force developed a list of "needs" that emphasized the new challenges that ecosystem direction brings to forest planning and management, with particular emphasis on technological requirements (Figure 1.1). This exercise was not pursued to the point of comprehensively identifying all possible needs, nor were the individual need statements fully refined. Rather, the ecosystem management introduction and review of needs provided a shared basic understanding of the scope and goals of the Task Force process.

- Decision makers will have to consider more factors and at a broader spatial domain and a longer time horizon.
- Disturbances will have to be incorporated as integral parts of the ecosystem process.
- Structure, function, and composition of ecological systems, social and economic systems, and the inter-relationship of both will have to be monitored and managed.
- Data needs will escalate, and with more extensive data, navigation tools that will provide better access, integration, and management of information will be required.
- We need to: 1) characterize ecosystems at different temporal and spatial scales; and 2) identify patterns and processes important at different scales.
- We need to determine which economic and social needs can be met while maintaining the ecosystem.
- A larger group of stakeholders and a broader public will have influence and will need information and understanding.
- Ecosystem management decisions must be made now despite the fact that our scientific knowledge is incomplete.
- Adaptive management is experimental, therefore we need to monitor and evaluate our effectiveness.

Figure 1.1: Summary of "needs" arising from the forest ecosystem management approach.

Each of the five Task Force groups worked independently on the technology development area to which they were assigned. Progress in each group was communicated in periodic plenary report and review sessions. Each group was given liberty to define their mission and to develop their own procedures, though a general "convergent analysis" approach was suggested as a common template across the groups. All groups were required to develop individual *Challenge* and *Mission* statements, a *Conceptual Model*, and a table listing *Major Activities and Products* along with estimates of budget and time resources need to accomplish each. The liberal, but not totally unrealistic budget constraint given to each group was five million dollars over a five year period. There was neither time nor adequate information to develop budgets with great precision; the figures provided are intended only as rough, relative level-of-effort estimates. These figures will, of course, be successively refined in subsequent strategic plans and detailed annual work plans.

1.2 Compilation of the Report

The compilers of the Forest Health Technology Task Force Report were all members and participants in the Task Force, and together represent all five working groups. Initial drafts of the individual group reports were prepared based on notes, flip charts, and other documentation collected at the Task Force meeting. These drafts were refined and compiled in a week-long writing workshop, resulting in this draft report to be reviewed by all members of the Task Force and to the National Forest Health Challenges Focus Group. The final report, incorporating reviewer comments and recommendations, will represent the collective efforts and the concurrence of the members of both groups.

Because the individual groups defined their mission and developed their concept plans independently, there is understandably some variability in the approaches and the levels of analysis represented. There are a number of instances of overlap between groups, some obvious but "missed" opportunities for explicit linkages, and some potentially important gaps between groups. Because the primary goal of the compilers was to faithfully capture and record the thinking and conclusions of each of the independent Task Force groups, it was decided to allow the unevenness, overlaps, and gaps to remain. Gaps, overlaps, and linkages between the five topic areas will be addressed during the development of the FPM/MAG Strategic Plan and the subsequent annual work plans. There was no effort to "fix" the content that naturally resulted from the independent group process that the Task Force followed. There was, however, an effort to edit the chapters into a common style, format, and structure in order to facilitate reading.

1.3 Background

Public land managers face myriad challenges in implementing ecosystem management. They must continue to comply with the complex system of existing laws and regulations. In addition, they must now try effectively to:

1. Account for the concerns and desires of a substantially broadened, diverse and increasingly volatile set of stakeholders;
2. Incorporate a rapidly expanding body of technical knowledge and data;
3. Understand and communicate outputs from increasingly complex and abstract biological, social, and economic models that now must project effects over large temporal and geographic scales; and
4. Document and justify management decisions that will routinely be challenged in uncertain political and legal arenas.

In the 21st century, ecosystem management analyses and decisions will increasingly be made in a "fish bowl" environment, where managers, environmental and resource scientists, members of special interest groups, and the general public will all be involved.

The challenge of Forest Health Technology 2000 is to harness the power of modern and rapidly emerging information technologies in the service of forest ecosystem management and decision making. A significant part of the mission is to ensure that this technology is an enabling force for defining, achieving, and maintaining desired future environmental conditions, rather than

an expensive and imposing technological barrier to managers and the publics they serve. To this end, the Forest Health Technology Task Force created conceptual plans for the development and delivery of five major components of technological support systems for forest ecosystem management.

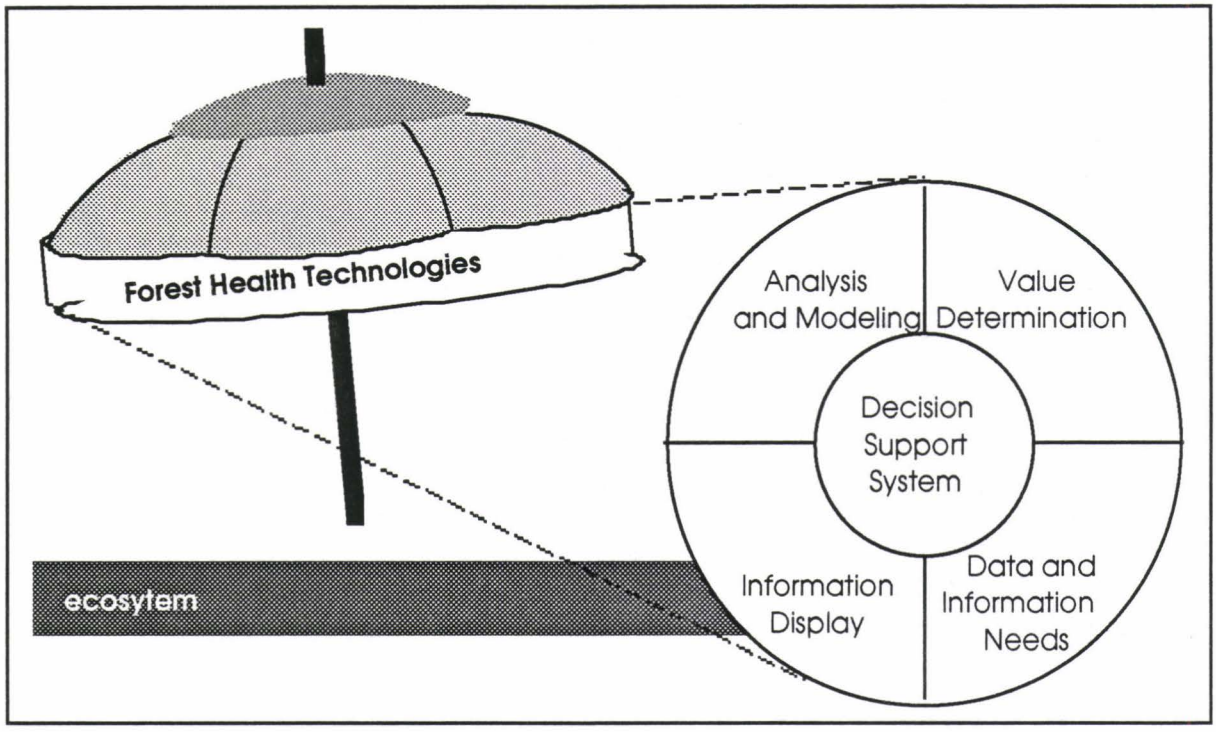

Figure 1.2: "Technology Umbrella" for forest ecosystem management.

Five related technological components are integrated into a flexible, but carefully coordinated support system to provide the major information needs of forest ecosystem management:

The **value determination** component helps managers to identify stakeholders, define the values that they hold which are relevant concerns for ecosystem management, and to appraise and systematically represent the effects of particular management actions and outcomes on those values.

The **data and information needs** component ensures that data design, collection, standards, archiving, access, and meta-data serve the decision needs of ecosystem managers and other data users, and that data on agents of change are included in the technical Geographic Data Committee's national vegetation layer data base.

The **analysis and modeling** component provides managers with analytical models of forest ecosystem processes at stand to landscape levels, involving insects, pathogens, fire, and other disturbance factors. These models will be used to quantify the ecologically possible desired future conditions and to translate the effects of forest management actions into responses in vegetation-based indicators.

The **information display** component facilitates communication about ecosystem management issues among managers and the diverse set of stakeholders through a suite of visualization tools that enable exploration of complex ecosystem relationships and provide concrete displays of the consequences and trade-offs implied by different management scenarios.

The **decision support** component will develop the integrating frameworks that package the elements of the other four components into user-friendly, accessible tools that provide genuine decision support to all stakeholders involved in ecosystem management.

Together, this coordinated set of modern information technologies will provide the powerful arsenal of tools required to meet the challenges of forest ecosystem management. In the following chapters of this report, the Forest Health Technology Task Force has provided a broad vision and guidelines for the development of this integrated technology umbrella for forest ecosystem management.

2.0 Value Determination

2.1 Challenge

Forest management has always been, and must be, value driven. The adoption of ecosystem management philosophy adds non-traditional values, such as *sustainability*, *resiliency*, *biodiversity*, and *forest health*, as well as placing new emphasis on "human dimension" values, such as *community stability, aesthetics,* and *outdoor recreation benefits*. The Forest Service must be able to identify emerging public values, and to use scientifically-based social and biological knowledge to determine how well management alternatives address these values. In order to best consider trade-offs and conflicts, managers need to understand the nature of the values being considered, and to have value information available in an organized, comprehensible form.

2.2 Mission

The Values Determination Group determined their mission to be:

> *To create a plan for developing methods and technologies to identify, measure, and display forest ecosystem values and to systematically relate these values to alternative forest ecosystem management actions and outcomes.*

2.3 Conceptual Model

Because public land management is value driven, determining the array of relevant values is a prerequisite to effective forest ecosystem management. These values determine the goals and objectives of management, influence which actions might be taken or disallowed, and direct what data should be collected and monitored, which processes should be modeled, and which indicators need to be produced by those models.

Values— be they spiritual, cultural, scientific or personal--are derived from the needs, wants and concerns of people. The particular values which are recognized at any given time, and the relative importance of those values, may vary depending upon personal, social, or environmental circumstances. For example, there is currently greater recognition of the importance of biological or ecological values, such as biodiversity and ecosystem sustainability. Whether these values are somehow "inherent" (independent of human wants and needs), a reflection of a transient interest in the environment, or are based on greater awareness of human dependence upon the natural ecosystem, ecological values potentially compete with a large number of economic, cultural, aesthetic, and other values in directing forest ecosystem management. The overall goal of forest management is to achieve desirable, or at least acceptable balances among the relevant values: "the greatest good for the greatest number in the long run."

The array of values which are relevant to forest ecosystem management and the constituencies who hold those values are large and diverse, and conflicts are common. Concerns and effects range from economic to cultural to environmental, from immediate to very long-term,

and from site-specific to landscape and even global scales. In this context "value" must be viewed as multidimensional; it is neither possible nor desirable to force all concerns onto a single dimension.

The general conceptual model adopted by the Value Determination Group is presented in Figure 2.1. This model distinguishes four primary components: *Stakeholders, Held Values, Indicators* and *Assigned Values*. Briefly:

Stakeholders are any persons, groups, or institutions which have an interest in the outcome of forest management activities. This definition includes local, state, or federal governments whose values may be expressed in the existing body of relevant laws; the environmental/land management agencies, whose values, in part, are expressed in the form of regulations and policies; and any other affected and/or concerned individuals, groups, or institutions existing now or in the future.

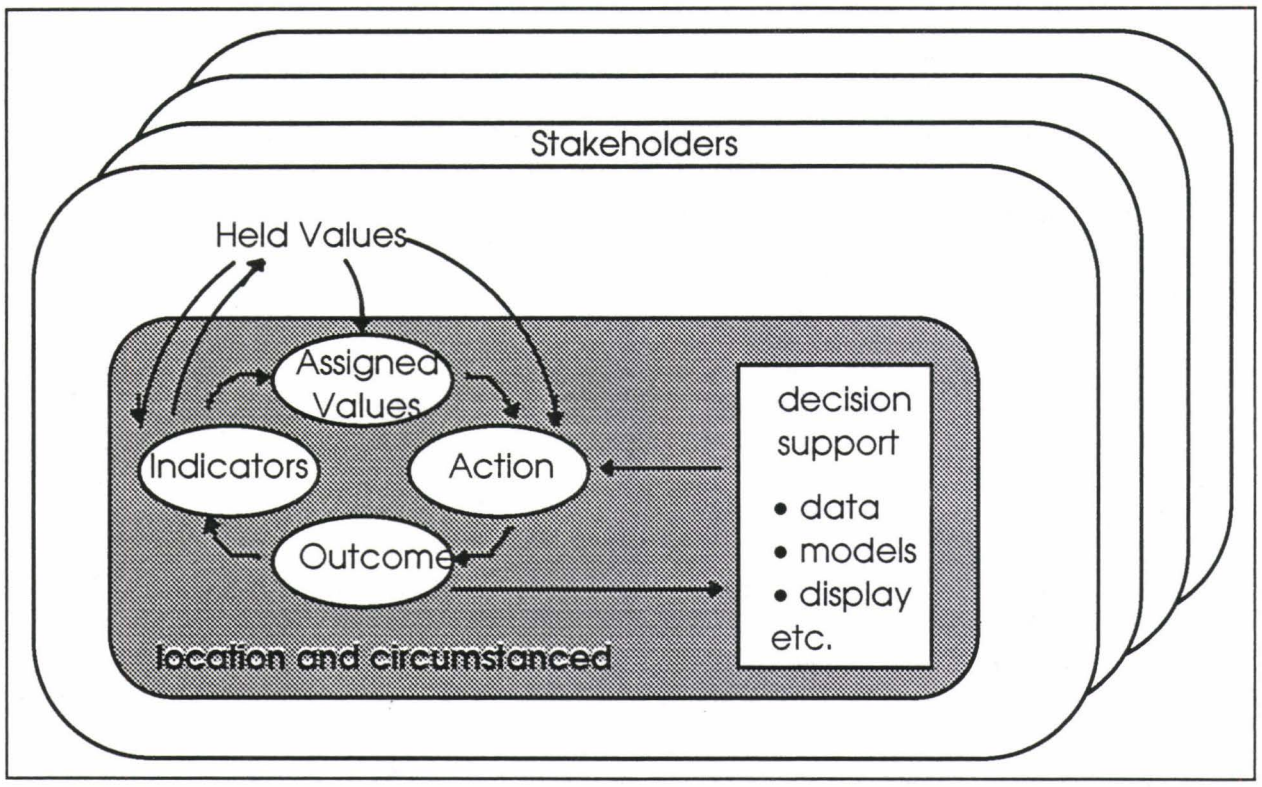

Figure 2.1: Conceptual model for a value determination system

Held values are general concepts of "worth", "goodness", or preferability which stakeholders consider to be important. Held values can be identified without reference to a specific context or a particular geographic location; that is, held values are relatively stable and enduring. For example, in the broadest sense *honesty, generosity,* and *intelligence* are often commonly held values. In the context of forest ecosystem management *biodiversity, economic productivity,* and *aesthetic quality* are held values for at least some people.

Indicators are observable and to some extent measurable features, conditions or states of the economic, social, and/or biological world which are relevant to one or more held values. For example, the number of mating pairs of owls may indicate one aspect of *biodiversity,* and the number of jobs may indicate the *economic prosperity* of a community. Ideally, the effects of management outcomes on relevant value indicators would be predicted systematically by models, providing a basis for choosing among alternative actions.

Assigned values are derived from the specific application of held values to aspects of a particular management outcome at a particular place and time. Whereas held values are more generic concepts which can be discussed in the abstract, assigned values depend upon which held values and associated indicators are relevant to a specific location under a specific set of circumstances. For example, suppose that *biodiversity* is a held value for some stakeholders, and *biodiversity* is generally indicated by the extent and condition of wildlife habitats and the number of viable wildlife populations and plant communities in an area. While many forms of indicator-value relationships are possible, in the simplest case, increases in the extent of habitat and the numbers of animals and plants would yield consistent increases in biodiversity value (i.e., a positive linear relationship). Thus, if the outcome of a particular management action is to reduce the extent and condition of habitats and the populations of animal and plant communities, that outcome will be assigned lower *biodiversity value* than an outcome which maintains or increases these habitats, populations, and communities.

While all of these components are interrelated, the conceptual model can be elaborated more clearly by discussing it in two stages. The first stage focusses upon Held Values, where Stakeholder-Held Value-Indicator relationships are emphasized. The second stage focusses upon Assigned Values, where the effects of management outcomes on Indicators relevant to applicable Held Values determine the relative preferability or "worth" of those outcomes.

Held Value Component

This component of the conceptual model is particularly relevant to the preliminary stages of planning. At this point, some initial assessment and understanding of the individuals, groups and institutions which may be affected by anticipated changes in the forest and/or by contemplated management actions, and the set of held values (issues and concerns) which may be relevant is important. Figure 2.2 illustrates the relationships among Stakeholders, Held Values, and Indicators.

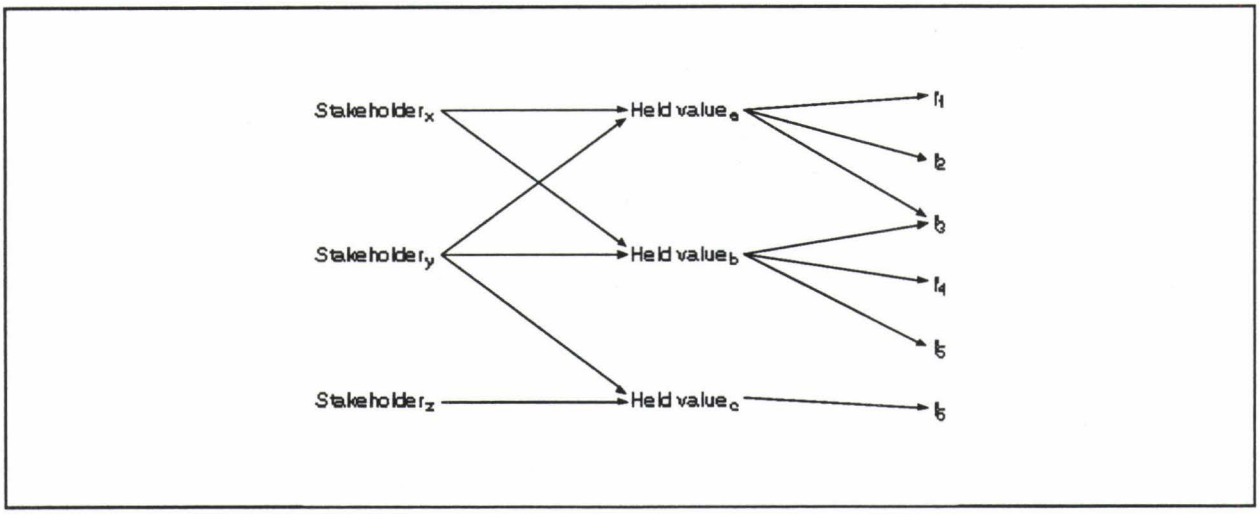

Figure 2.2: The relationships among Stakeholders, Held Values, and Indicators.

Held Values are unobservable constructs (feelings and/or concepts) which are inferred from the relationship between identifiable Stakeholders and the observable Indicators which they judge to be important. For example, for some anglers (a stakeholder) "good fishing" (a recreational/aesthetic held value) may depend upon: 1) the number of fish caught per unit time; 2) the average size of fish caught (both positive indicator-value relationships); and 3) the number and type of other people encountered while fishing (a negative indicator-value relationship). In the same context, the management agency (another stakeholder) may be required by law to protect some endangered aquatic species (an institutionally established held value) by maintaining critical habitat and restricting or prohibiting fishing on the stream. For some members of local communities which depend upon providing goods and services for anglers, this policy may adversely affect economic stability (and perhaps some cultural values) by reducing traditional jobs and income.

As Figure 2.2 indicates, any given stakeholder may have more than one relevant held value. In any given context these held values will have different priorities (and there will probably be a great many more held values which are not relevant to forest ecosystem management at all). Several stakeholders may share one or more held values, but with differing priorities; i.e., biodiversity and aesthetic quality may both be important different stakeholders, but one may feel that biodiversity is more important while the other places more emphasis on aesthetic quality. Similarly, each indicator may be related to more than one held value, and different indicators may have greater or lesser "weight" in relation to different held values.

Depending upon the context and the level of analysis applied (e.g., a coarse or a fine level of analysis), stakeholders may be aggregated into rather large classes (e.g., environmental interest groups, urban vs. rural communities, etc.) or differentiated into many classes at the finest level it may be that every individual has some unique pattern of held values. Similarly, indicators may be aggregated into higher level indices (e.g., various biodiversity or site-productivity indices), or dissaggregated into more detailed components (soil types and depths, numbers of specific species, or condition of individual animals or plants). At each level of analysis, a particular held value is

defined by the relationship to its associated indicators; different indicator relationships require, by definition, different held values.

Assigned Value Component

Assigned values are most relevant in the later stages of forest ecosystem planning, during the evaluation and selection of specific management alternatives for particular sites. The key questions at this point revolve around the relative effects of each alternative on value-relevant indicators (and thus upon the interests of associated stakeholders).

From the perspective of value determination, all management outcomes are conceptualized in terms of the levels attained on each of some constellation of indicators. For example, a given outcome may be characterized as "X acres of high quality owl habitat, Y cubic volume of harvested saw logs, and Z visitor days of medium quality recreational fishing." Based on their relationships to particular held values, each of these indicator levels is related to some assigned value on one or more value dimensions (e.g., biodiversity, economic productivity and fishing quality). Thus environmental outcomes are translated by the held value-indicator relationships into Assigned Values, as indicated in Figure 2.3. As suggested in the figure (and in Figure 2.2 above), each indicator may be related to more than one assigned value, and thus may contribute (with different weights) to several assigned values.

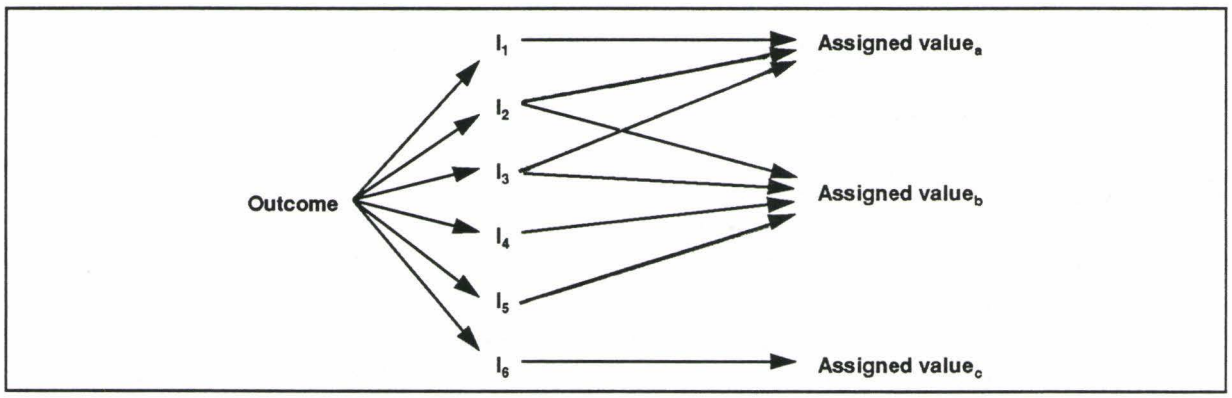

Figure 2.3: The "outcome" of forest ecosystem management decisions is expressed in terms of indicators, which are translated into Assigned Values.

The Assigned Values depend upon the indicator level achieved, and relative importance or worth assigned to each level. Indicator-assigned value relationships may be positive (e.g., increasing amounts of owl habitat yields increasing biodiversity values) or negative (e.g., increasing numbers of fishermen/women yields decreasing quality of fishing experience, for some anglers). These relationships are not always (or even typically) linear. For example, the increase in economic productivity produced by increasing volumes of saw logs typically decreases at some point, depending upon available mill capacities and the demand for saw timber (i.e., the classic economic concept of decreasing marginal utility). Some indicator-value relationships can be non-monotonic.

For example, at some point increasing numbers of recreation visitor days, which at low to intermediate levels may yield increasing recreational value, can begin to be negative; too many recreators in an area can degrade the quality of everyone's experience more than the overall value is increased by having more people to share that experience.

Because multiple stakeholders and held values are always involved, any comparison among management outcomes requires consideration of multiple assigned value dimensions. For example, one outcome may be assigned higher values than other alternatives for biodiversity, but lower values for recreational or aesthetic qualities. Figure 2.4 illustrates this concept for a simple two-value dimension case.

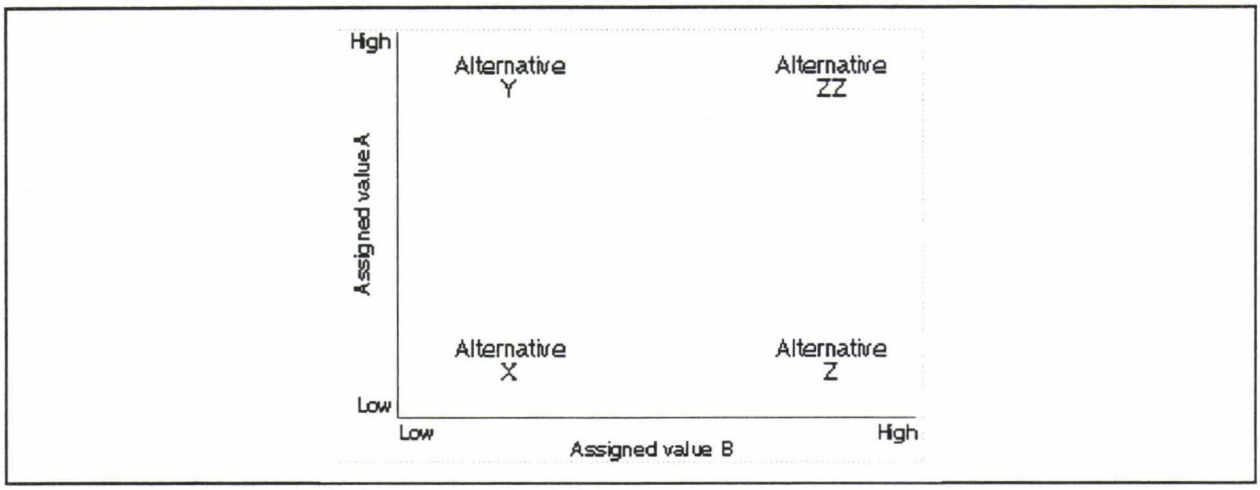

Figure 2.4: Illustration of multidimensional comparison of the assigned values for four hypothetical management outcomes.

Notice that hypothetical Alternative ZZ is an unambiguous "winner" in this example, it achieves the highest level on both assigned value dimensions shown. Similarly, Alternative X is an obvious looser. Difficulties arise with Alternatives Y and Z. While Alternative Y does much better on dimension A, Z does much better on dimension B. Here the decision maker must "trade-off" levels of assigned value A against levels of assigned value B; the choice between alternatives Y and Z will depend upon (or will imply) the relative priority assigned to each value dimension.

Some evaluation/decision-making models require that all values be translated to some single omnibus "commensurate" scale (e.g., dollars, subjective utility, or importance), reducing the final choice among alternatives to simple arithmetic. However, the Value Determination Group was not prepared to adopt any existing uni-dimensional value approach. Thus, the goal for the value determination system with regard to assigned values is to find means to structure and display the locations of alternative management outcomes in a multidimensional value space so that decision makers can more clearly and systematically make comparisons and investigate trade-offs, among alternatives as a basis for their final selections.

2.4 Strategy

We feel that the long term goal of the value determination component should be to develop an integrated system which incorporates various aspects of collecting, storing, and organizing information about stakeholders' values, as well as providing indicator measures for forest health management alternatives. Individual components of this system should be developed and implemented as stand-alone tools. This would allow feedback and modification of these components as they are developed.

A handbook-style document should be developed and distributed early in the process. This document would serve as both a primer on the concepts and measures used in different disciplines to describe values, as well as a "how-to" guide and checklist for incorporating consideration of relevant values in forest health planning and project decisions. Having this document early in the development of value determination tools will provide better feedback on managers' needs.

Our objectives focus on how to gather, organize, and display value information to helpselect management alternatives. Objectives generally can be met through reviewing research and previous applications of techniques, determining the state of valuation methodology in various disciplines, and developing new or modifying existing methodology for field application.

2.5 Objectives

The plan of the Value Determination Group has the following six objectives:

1. ***Document the set of held values which are currently relevant to forest ecosystem management, and reference each value to: 1) the stakeholders who hold those values, and 2) appropriate indicators for measuring and monitoring those values.***

Much of the Value Determination portion of this report deals with identification and development of tools and information which will help guide ecosystem management. Some recognition of values needs to be incorporated into management planning and activities which are taking place right now. This first objective will provide the necessary information to managers in the short term, concurrent with the development of more powerful tools for obtaining and analyzing this information in the longer term. It is not enough to simply identify the held values: it is essential to know which stakeholders hold which values, and what indicators are appropriate to measure and monitor these values.

2. ***Develop methods to identify the values, stakeholders, and indicators and determine how each may change over time.***

Collecting information on the range of values which are held by all of the stakeholders, and how these values can be measured and monitored, should be a continual process. Values change over time, and this needs to be documented. Unlike the first objective, which focuses on *content* to help guide ecosystem management now, this objective focuses on *methods* for determining held values both now and in the future.

3. *Develop methods to determine and measure assigned values for alternative management outcomes.*

Identifying held values helps managers understand the scope of their task, but does not help them with site-specific planning. For this, they must also understand, on a site-specific basis, how assigned values might change under different management outcomes. This objective links indicators developed through biological and social impact analyses to their effects on values.

4. *Develop methods to structure and express the diversity of values among stakeholders.*

Applying held values to specific sites and management regimes can produce added dimensions of complexity. Different stakeholders may share common held values, but the way in which they assign these values in site-specific cases may differ. The priority they give to the range of values may also differ. For example, stakeholders A, B and C may all be concerned about spiritual, cultural, and economic values. Stakeholder A, however, may think that a particular forest condition has high spiritual value, whereas stakeholder B may think that it has only moderate spiritual value. In addition, stakeholder A may think that the cultural value of that forest is more important than timber values, whereas stakeholder C may think that the timber value of the forest and the associated economic values should take precedence. All of these dimensions should be recognized and considered during site-specific planning.

5. *Determine methods to compare and examine trade-offs among values across ecosystem management alternatives.*

It is not enough to simply identify the set of assigned values for specific management outcomes; comparison of different management alternatives in support of a decision requires that the trade-offs among the expected outcomes be examined. Examining these trade-offs necessitates the consideration of the multiple dimensions discussed under objective 4. Meeting this objective will contribute techniques useful for a DSS.

6. *Develop methods to communicate among stakeholders about held values and assigned values.*

Incorporating value determination in decision-making requires information flow among all stakeholders, particularly between the managing agencies and other stakeholders. The goal is to have very well-informed stakeholders who understand the implications that different value sets might have on management actions and outcomes.

2.6 Major Activities and Products

A number of projects have been identified to achieve these objectives:

1. *Determine relevant held values, stakeholders, and indicators for ecosystem management*

A great deal of information is already available on what held values are relevant to ecosystem management, who holds them, and what the primary indicators are for these values. For specific forest health issues, an extensive search of this information would take place in the first phase of the project. Potential sources include forest plans, the social and biological sciences literature, court proceedings, and the media. This information could be approached from both directions: information obtained on values would lead to information on the stakeholders who consider those values to be important, and information on stakeholders would lead to information on their held values. Separate routes of inquiry may be necessary to identify which indicators are most appropriate for the identified values.

Phase 1 of this review would result in a comprehensive listing of currently-held values and their constituents. Each value would be linked to at least one stakeholder group and have at least one indicator.

Phase 2 would refine the stakeholder--held value--indicator relationship. Stakeholders who have been associated with a held value should be consulted to determine if that indicator list is sufficient to represent their values. This process of refining the indicator list and re-consulting with stakeholders may require several iterations. Research recommendations may also emerge from this phase, as there may be values for which specific indicators have not yet been identified, or agreed upon.

2. *Develop methods to identify, project, and monitor values, stakeholders, and indicators*

The first step in developing methods is to critically review existing approaches. Appropriate methodologies may be directly adapted from existing methods, or new methodologies may incorporate elements of existing methods. The review may indicate the need for new methodologies to meet the needs of ecosystem management.

The second step would be to develop project plans for adapting/developing methodologies. The range of potential methodologies may include focus groups, workshops, E-mail/bulletin boards, electronic townhall surveys, gaming simulation designed to reveal values, and behavioral observation techniques.

Following the completion of the project plans, development of the methodologies would begin concurrently. However, their completion dates would depend on the degree of development necessary, the complexity of the methodology, and the resources available for the task.

As soon as any particular methodology is completed, steps should be taken to transfer the technology/methodology to the rest of the Forest Service and other relevant parties. This technology transfer would be repeated for the subsequent methodologies as they are completed.

Activities and Products:

- A critical review of existing value identification, prediction, and monitoring methods.
- Develop and test value identification, prediction, and monitoring methods for ecosystem management.

3. *Develop methods to determine and measure assigned values for alternative ecosystem management outcomes*

This project will produce a handbook for determining and measuring assigned values. The first task would be to review and evaluate methods for determining and measuring assigned values for alternative management scenarios. These may include the following methods:

- economic, such as travel cost, contingent value and hedonic pricing techniques;
- perceptual surveys, such as the Scenic Beauty Estimation method for visual aesthetic quality or similar approaches for determining quality of recreation experiences;
- attitudinal surveys, including verbal questionnaires, telephone surveys, or face-to-face interviews;
- community/social indicators, archival analysis methods based on census data, community economic records, etc.;
- cultural/heritage approaches in which consensus criteria are developed for classifying historic sites or unique natural environments.

At the same time, a framework would be developed which would help managers decide on the best approach for determining assigned values in various contexts. Different approaches would be possible, depending upon the desired level of analysis (coarse/fine). At a coarse level, assigned values would be determined using general or common knowledge, perhaps through an expert system using a very simple set of rules. A fine level approach would require a much more site-specific consideration of factors, and may require use of a specific survey or analytic procedure to determine specific assigned values. The framework would guide managers through these approaches, and include a list of criteria to help managers determine what level of analysis to employ, and which specific methods are most appropriate for a given decision/problem.

Once the catalogue, framework, and criteria are complete, they would be combined into a handbook which would assist managers in determining and measuring assigned values in the short term. This handbook may be a hard-copy manual, or may alternatively be provided in an electronic format.

As needs are identified, new methodologies would be developed. The purpose would be to provide powerful and sophisticated evaluation tools for application to ecosystem management. The development of the methodologies for assigned values would proceed according to need and resources.

Activities and Products:

- A catalogue of methods for determining and measuring assigned values, based on a review of scientific and applied literature.
- A framework for using coarse to fine levels of analysis approaches for determining and measuring assigned values with a set of criteria for selecting the most appropriate approach.
- A handbook to guide the application of specific assigned value determination methods.
- Development of new methodologies as determined by need and resource availability.

5. ***Develop Value Referencing System (VRS)***

The VRS would be a multi-modular expert system which would contain:

- a catalogue of held values, the stakeholders who hold them, and relevant indicators for measuring them.
- a framework and criteria for determining the most appropriate level of analysis;
- recommended methods for identifying and defining relevant values; and
- a means for maintaining an institutional memory of what values were considered in past management decisions, and what methods were used to define values.

Much of the information that the system would provide would be produced through the projects described above. The bulk of this project would be the design, testing, and implementation of an expert system for accessing, displaying, and justifying this information.

The VRS could be used in a number of ways. Managers could query for a particular stakeholder to find out what values they are concerned about, or query for a particular held value to find out which stakeholders are likely to be concerned about it. Managers could also find out what indicators they should be considering in their data collection or modeling efforts, based on particular held values, as well as determine to what held values a particular set of indicators might apply. Other databases that may be accessible through this expert system might include census data, Tiger Files, IMPLAN data, and city/state/national economic and demographic databases.

The first step in producing the VRS would be to develop the architecture for the system, within the Forest Service Information Management framework. The development of the VRS would proceed in discrete steps. The first prototype for the VRS would be the printed Held Value/Stakeholder/Indicator catalog (Objective 1). This prototype would undergo field testing and refinement, followed by additional, more refined prototypes, until a final computer-implemented system is developed.

Activities and Products:

- Design document and development plan for the VRS.
- Prototype VRS for testing as beta release.
- Full working version of the VRS.

6. ***Develop system for structuring and displaying assigned value sets in a multidimensional fashion***

Because multiple values must always be considered in ecosystem management, it is important to identify and structure all relevant value sets - to map management outcomes in a multidimensional value space - for a particular management site under current conditions, then predict (preferably with models) how relevant indicators might change under different management scenarios. The purpose would be to help inform selection among management alternatives.

This system needs to include the capability to analyze the importance of a particular indicator with respect to how it changes with different management outcomes. For example, if various management alternatives being considered do not have any significant impact on a given indicator, then including the associated assigned value in the multidimensional structure/display may not be a high priority.

The first step in system development would be to review existing methods. These methods indicate the range of the review: economic analysis; gaming (simulation); multidimensional mapping; develop preference sets; linear and non-linear programming (include sensitivity display). Based on this review of what is currently being done and what techniques are currently available, the architecture for the system would be developed. System development would follow the Forest Service Information Management framework.

The first prototype of the system would only display and structure the value space; the first full version following this prototype would include the capacity to modify the dimensions of the multidimensional value space. This technology is related to issues within the Information Display Group of this Task Force.

Activities and Products:

- Report describing existing methods.
- Design document and development plan for multidimensional value space system.
- Prototype for displaying the value space.
- Version 1.0 of the system with a prototype module allowing the user to adjust the dimensions of the value space.
- Full working version of the complete system.

2.7 Resource Requirements

Table 2.1 displays the specific project development activities, and cost, and time required in years. The cost estimates are ball-park estimates, they include salaries but assume that cooperator institution and overhead costs will be nominal.

Note that for budgeting purposes, the cost information for project 2 (developing methods to identify and track values, stakeholders and indicators) assumes that development of three new methodologies will be recommended, and all three will require major development efforts. The degree to which currently available methods may be adapted to meet these purposes will reduce the cost of this project.

Table 2.1: Resource requirements for the Value Determination Group

Major Activities and Products	Cost ($1,000)	Duration (years)
Determine relevant held values, stakeholders, indicators	750	2
Develop methods to identify and track values, stakeholders, and indicators	600	5
Develop methods to determine & measure assigned values	950	5
Develop Value Referencing System	1,125	4
Develop system to structure and display assigned value sets	1,075	5
Total	4,500	5

3.0 Data and Information Needs

3.1 Challenge

Quality data and information are the foundation for credible decision making. Ecosystem management will require unprecedented volumes of data, and information at exceptional and multiple levels of temporal and spatial resolution. A key challenge to the successful implementation of ecosystem management is the development of a national spatial data hierarchy. This hierarchy will provide a framework and base level of vegetation data into which all other data can be nested. The development of this framework should be an interagency effort involving both federal and state cooperators. Its development will provide a base level of data which will truly allow data collection, analysis, and modeling across ecosystems, regardless of ownership.

3.2 Mission

The mission that the Data and Information Needs Group set was to create a plan which would:

A. *guide efforts for evaluating, developing, and transferring to FPM field units and other interested parties appropriate technologies for data collection, management, and analysis, particularly as related to occurrence and extent of forest vegetation change agents such as insects, pathogens, fire, and other abiotic factors;*

B. *meet the data and information needs of forest ecosystem management, including FPM and other field units;*

C. *ensure that ecosystem change and disturbance data and information needs are considered.*

3.3 Conceptual Model

To meet the above challenges, and achieve the stated mission, the Data and Information Needs Group developed a comprehensive, and adaptive program that is illustrated, in schematic fashion, in Figure 3.1. This figure shows four major streams of activity, which correspond to the four activity areas described later in Section 3.6.

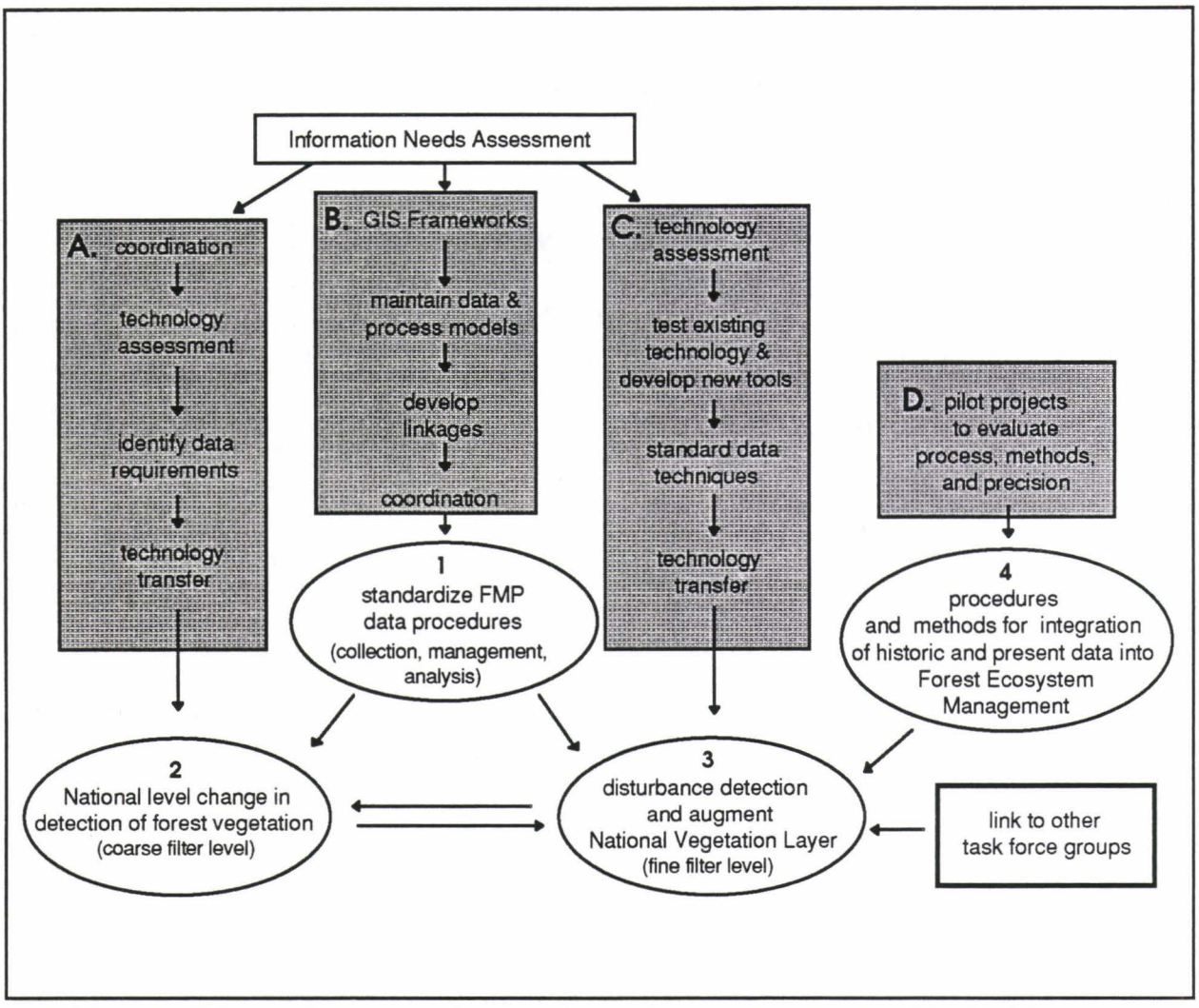

Figure 3.1: Conceptual model illustrating the four data and information needs activity areas.

Implicit in this model is the concept of data resolution and hierarchy. In order to accurately monitor and model cumulative ecosystem dynamics, we must be able to distinguish smaller, more frequent disturbances, rather than just larger, more catastrophic disturbances. Data must be hierarchically nested, going to the highest resolution needed for the "design case", then extrapolating to increasingly smaller and smaller scales (if the sample is sufficiently statistically based). There are three main scales of interest:

Coarse: high resolution data (1 hectare) with a broad classification system (Anderson level 2 or its successor) on a continental basis,

Fine: same resolution, but greater classification detail to meet the needs of each ecosystem,

***Local*:** traditional forest/project data at the stand level with traditional Forest Service attributes covering volume, structure, etc. These data should be re-collected every 3-5 years.

Data must be spatial as well as tabular, allowing people to "see" and intuitively understand the data.

3.4 Strategy

As shown in Figure 3.1, the basic strategy is to begin with a detailed information needs assessment (INA). This will help in defining the data that must be collected, maintained, and exchanged to complete the ecosystem management mission. The INA provides a solid foundation and a common starting point for three of the four parallel streams of activity in the data and information needs area. Activity stream B (Figure 3.1) is intended to translate the results of the INA into standard frameworks and data procedures (e.g., collection, management, analysis) that will foster and streamline the acquisition and use of data and information.

Two of the activity streams (A, C in Figure 3.1) are intended to ensure that the methods, procedures, and technologies needed for detecting forest vegetation change are developed and transferred to the people who need them. The reason that there are two streams relates to two different scales of change detection. Activity stream A is intended to advance the capability to detect change on a continental basis with a resolution of 1 ha, whereas activity stream C will encourage development of capacities for detecting changes at a finer, local level (e.g., stand). The fourth activity stream (D, Figure 3.1) is designed to improve our abilities to collect and analyze landscape level data on pathogens and insects, with particular emphasis on stressor regimes.

Together, these four activity streams represent a body of activity and work that will significantly advance the quality, accessibility, and use of data and information needed for effective ecosystem management in the early years of the next century.

3.5 Objectives

The data and information needs portion of this report is designed to meet the following four objectives:

1. Standardize data collection, management, and analysis procedures.

The objective is to standardize data collection, management, and analysis procedures in concert with the Information Management Framework. In addition to vegetation data, this includes data on forest vegetation change agents (insects, pathogens, fire, and other abiotic factors), and forest protection activities. This will be accomplished through an information needs assessment.

2. Automate detection of forest vegetation changes due to natural and anthropogenic causes.

The intent is to establish (in concert with others) a coarse-scale national vegetation database and the supporting technology and procedures required to automate the detection of changes in forest vegetation structure and composition due to anthropogenic and natural causal agents.

*3. **Produce a database containing fine- and local-scale information on forest vegetation and change agents.***

To allow changes in forest health and their causes to be discerned at the forest ecounit (stand) management level, a database will need to be developed and maintained that augments the national vegetation database with higher spatial, attribute, and temporal resolution information.

*4. **Develop data and methods for analyzing pathogen and insect regimes at the landscape-level.***

Knowledge of the natural variability of pathogens and insects is an integral part of ecosystem management. The data and methods to be developed under this objective will help provide a scientific basis for assessing the sustainability of forest ecosystems.

3.6 Major Activities and Products

3.6.1 Standardize data collection, management, and analysis procedures

Ecosystem management will require collecting and analyzing a wide variety of data types: (e.g., pest occurrence and impacts, protection activities, and vegetation data). In the future, even more data will be required, from a wider variety of sources. It is essential that data from all sources be consistent, and that they be designed, collected, stored, and managed to meet forest ecosystem management needs. It is critical that data to be collected, maintained, and shared among cooperating units be defined. This will be accomplished through an information needs assessment. The document *Information Management: A Framework for the Future* (USDA Forest Service Strategic IM Team, February 1992) provides not only the Forest Service vision of an integrated environment, but also a framework for accomplishing that objective. Furthermore, the document *Information Management: Implementation Master Plan* (May 1994, in draft) details some specific steps that will be taken over the next few years.

Task 1: Information needs assessment

The Forest Service recently completed the *Agency-Wide Strategy Stage* (AWSS) *Study* (in draft) that identified several focus areas, each of which is a "cohesive subset of the agency's business and information needs." To be a full participant in Forest Service information management (IM) activities, forest change and disturbance factors must be identified as one of the focus areas of concern to the Information Systems and Technology (IS&T) unit. The initial task to be completed for a focus area is the completion of the strategy and analysis stages, as outlined in the Forest Service *Methodology Consensus Report* (March 1992). The report identifies the process for engineering and integrating all Forest Service information. This process will identify the data required and what USFS units will be the steward, as well as the data that unit requires from other staffs and agencies to accomplish its mission. In addition, the process must address data collection and management in a spatial and temporal context. It must address not only the data itself, but also meta-data, viz. data that describe the data.

Activities and Products:

- The strategy and analysis stages of the FS Methodology, or Information Needs Assessment, will be completed for the change and disturbance focus area following the process outlined in the Methodology Consensus Report. Over the next five years, this will be updated and modified as necessary. The Information Needs Assessment will be a detailed analysis, including documentation and data dictionary entries for all functions and entities included in the focus area.
- Spatial, spectral, and temporal requirements for the "coarse-scale and fine-scale" resolution forest vegetation change detection system will be defined. Information acquired and standards developed during this needs assessment will contribute to the GIS database design for coarse and fine level change detection efforts.

Task 2: Develop GIS database framework

Many of the data which are currently available were collected with reference to location, but are not stored in a spatially-oriented context. Potential linkages to the spatial framework provided by geographic information systems must be identified and established for analytical purposes in an ecosystem context. This initiative will also provide a framework for collection and management of data in a spatial context and for incorporation into geographic information systems.

Activities and Products:

- Integrated GIS Database Framework. This framework will include both:
  a) GIS data base framework and linkages to other data sources. Identify other GIS data sources which could potentially assist in Objective 2 & 3 analyses.
  b) Identify point of contact for interaction with the Federal Geographic Data Committee (FGDC). Contribute to data standardization efforts between agencies. Complete actual GIS data base design for Objective 2 & 3 analyses.

Task 3: Develop and maintain data and process models

Under ecosystem management, data requirements will change over time, resulting in the need to update data and process models.

Activities and Products:

- Maintain and enhance data and process models. Updates and revisions will be required as new information and technologies become available and as pilot projects are completed. This is seen as an iterative process.

Task 4: Develop links to external data sources

No single unit can serve as the steward for all of the Forest Service data needed to address change and disturbance effects; nor will other Forest Service staffs maintain all of the data which any single unit will need. As an example, FPM needs access to data in the National Pesticide Information Retrieval System, located at Purdue University. In order to take full advantage of the "information highway", FPM should have on-line access to this and many other data bases

maintained by other agencies and organizations. This is particularly true with respect to the FPM responsibilities for state and private forestry.

Activities and Products:

- An improved information flow within and between USFS units and their cooperators.

Task 5: Coordinate with other staffs and agencies

Ecosystem management and the Forest Service vision for an integrated information environment will require full cooperation and data integration across staffs. Moreover, access to data for lands outside of National Forest boundaries will also be required. Other required data may also be maintained by other agencies. Successful sharing of data outside of the agency will require cooperation with staffs and agencies throughout, and external to, the Forest Service.

Activities and Products:

- Liaison with other groups. This will provide ongoing communication and liaison among groups within the Forest Service (e.g., between Forest Pest Management and Information Systems and Technology). All related units should have representation in meetings with other agencies (e.g., Soil Conservation Service, USGS) and on federal committees (e.g., FGDC).

3.6.2 Automate detection of forest vegetation changes due to natural and anthropogenic causes.

All units should work with the Federal Geographic Data Committee to establish a national vegetation database for baseline conditions and to develop technologies and methods to automate detection of change in forest vegetation (structure/composition) nationwide, at appropriate spatial and temporal resolutions to determine rate and direction of change. FPM/MAG, in particular, should interact with other cooperators to provide data requirements beyond those required by the FGDC addressing the National Spatial Data Infrastructure, currently developing the national vegetation layer. This coarse spatial resolution component would have standards, developed by a federal consortium for content (vegetation classification), meta-data, geo-registration and projection, compatible with other FGDC spatial data standards, i.e., base cartographic data, soils, etc. The vegetation classification would then be aligned with the Forest Service Ecomap Hierarchy.

We recommend that FPM/MAG assume responsibility for developing automated disturbance/change detection procedures for anthropogenic and natural causal agents.

Task 1: Coordination with other agencies.

Strengthen ties among federal, state, and private efforts to develop forest vegetation data bases. Form partnerships and cooperative projects among agencies to pool resources, share data, and technical expertise. Consortia to acquire remote sensing data (aerial photography and satellite imagery) and integrated resource inventories will be required.

Activities and Products:

- Identification of requirements and contributions including data acquisition, data processing, data archiving, data standards, and product generation. Review existing classification systems as appropriate to support Objective 2 & 3 analysis. The data classification systems used for these analyses must comply with FGDC requirements. In addition to FGDC data requirements, more detailed information will be required to meet the needs of specific projects which exceed FGDC requirements.
- Ongoing coordination among federal, state and private efforts to develop forest vegetation data bases. Development of cooperative projects will leverage available funds and speed data base development.

Task 2: Technology Assessment

This is a very important activity in the FPM/MAG program and within the program of the Nationwide Forestry Applications Program of Engineering. The results of technology assessments are directly related to FPM/MAG's technology transfer program. The technology assessment activity includes evaluation of remote sensing systems, global positioning systems (GPS), aircraft instrumentation, image processing, data modeling, and analysis techniques for detecting forest damage and change.

The results of technology assessment projects will provide input for the development of new techniques and methods for monitoring forest health and ecosystem change. It is important to recognize that existing technologies may not totally fulfill needs. Modifications of existing technologies, or new technologies, may emerge to meet requirements for monitoring, mapping, and data base development.

Activities and Products:

- Conduct technical evaluation program to support Objectives 2 & 3. Identify existing technologies which have potential applications in Objectives 2 & 3 analyses. Define procedures and methods for properly using new technology and data analysis procedures.

Task 3: Identify spatial, spectral, and temporal data requirements

This activity is related to technology assessment and information needs assessment. For example, in order to identify a new remote sensing technology that is worthy of evaluation, The spectral, spatial, and temporal properties for the features to be imaged must be known.

Activities and Products:

- Through a series of pilot projects, develop models and analysis procedures for identifying vegetation change.
- Produce a handbook which includes the spectral, spatial, and temporal characteristics of these change agents.

Task 4: Technology Transfer

On a periodic and frequent basis, FPM/MAG should prepare reports and publications documenting the results of activities. These reports and publications are intended for internal and external distribution. Technical workshops, conferences, and training sessions provide additional forums for sharing information and results.

Activities and Products:

- Automated disturbance and change detection procedures. This will provide automated, but supervised, disturbance and change detection procedures for anthropogenic and natural cause agents at a coarse-scale.

3.6.3 Produce database containing fine- and local-scale information on forest vegetation and change agents.

Augment the national vegetation layer with higher spatial, attribute, and temporal resolution information, consistent with the national ecological unit hierarchy, so that changes resulting from insect and disease, fire, and anthropogenic causes can be determined at the forest ecounit (stand) management level. This database should be developed and maintained within FPM.

Task 1: Identify characteristics of ecological units and vegetation stressors needed to determine causes of disturbances

To identify characteristics of ecological units (land type associations) and stressors (change agents) needed to determine the causes of disturbances (changes) to forest vegetation.

Activities and Products:

- Documentation for how specific stressors affect particular ecosystems, including spatial and temporal resolution, spectral response, host characteristics, and abiotic considerations such as climate.

Task 2: Evaluate existing data collection techniques and technology regarding causes of change in forest vegetation

Conduct an evaluation of existing data collection techniques and technology used to meet information needs regarding causes of change to forest vegetation. The focus of this activity is at the fine-scale level across a landscape or multiple landscapes.

Activities and Products:

- Literature review and evaluation report, identifying needs for testing existing technology, or developing new technologies required for detecting changes and determining causes of change in forest vegetation.
- Evaluation of data collection techniques and technologies for stressors. This evaluation will focus on existing techniques and technologies, will highlight gaps in available techniques, and will provide a description of new technologies that are needed.

Task 3: Test and/or develop techniques and technologies for detecting changes in forest vegetation

Test existing techniques and technology and/or develop new methods to detect and determine change and causes of change to forest vegetation.

Activities and Products:

- Testing, development, and evaluation of techniques and technologies to detect and determine change in, and the causes of change to, forest vegetation.
- A handbook of tools and methods to be used for data collection. This will be in the form of a standardized list of causal agents and the technologies for their detection.

Task 4: Develop national standards for data and methods for detecting forest vegetation change.

Set national standards for data and collection methodologies used to detect change in forest vegetation. This activity will take several years to fully implement.

Activities and Products:

- Vegetation classification consistent with ECOMAP hierarchy. This will be a vegetation classification that is aligned with the Forest Service ECOMAP hierarchy. As well, through participation with the Federal Geographic Data Committee, a set of standards for the national vegetation layer will be established.
- Initial work on a set of draft standards and proposed methods, based on results from the needs assessment and evaluation activities.
- Draft standards and proposed methods for detecting forest vegetation change will be released.
- A test and review of the draft standards and proposed methods.
- Final standards and acceptable methods.

Task 5: Develop, test, evaluate, and transfer linkage capabilities to permit data exchange at the regional and national level.

This activity will support the population of individual GIS installations and their associated data bases. It will require the entire five-year period to fully implement, and assumes that the necessary GIS hardware and software will be acquired by each unit.

Activities and Products:

- A beta test of the linkage will be conducted. This will involve not only a limited test of the data link between two units, but also accessing one or two outside data bases. In addition, this task provides an early opportunity to test initial versions of the IM framework.
- The system will be further developed and refined

- A pilot project will be conducted over a regional or bio-regional area.
- Technology transfer sessions will be conducted with the appropriate field units.

Task 6: Ongoing coordination

An ongoing coordination effort will be implemented at various stages of tasks 1 through 4, above. This coordination will include state and local agencies, the USFS Washington Office, other federal and state agencies, FPM field units and cooperators, and technical experts in academia and industry.

3.6.4 Develop data and methods for analyzing pathogen, insect, and fire regimes and interactions at the landscape-level.

This task is to develop procedures and methods for integrating historic and present roles of insects, diseases, and fire into forest ecosystem management. The overall objective is to develop efficient, sound, and well-documented data sets and methods to perform landscape-level analysis and modeling of pathogen and insect regimes. These data sets and methods will blend with, and take advantage of, agency-developed and supported spatial data layers and associated attributes. The result will ensure that pathogen and insect considerations are an integral part of ecosystem health and sustainability analyses. These analyses are the first step in the hierarchical approach to ecosystem management that has been officially adopted nationally. Some issues that can be better addressed when such data and methods are available include: natural ranges of successional patterns; disturbance regimes for root disease and western spruce budworm; current distributions of pathogen and insect activities and regimes; and future trends to be expected across large landscapes. The natural range of variability, based on historic patterns of conditions and events, provides a scientific basis for assessing the sustainability of ecosystems.

This objective will be accomplished through two pilot projects, during which data standards and methods will be developed, tested, and refined. Lessons learned during the first pilot will be used to refine the process of the second pilot. During year 5, an evaluation of the process, methods, and precision will be conducted and a synthesis produced.

Task 1: Pilot project

Establishing the natural range of variability will provide a scientific basis for assessing one aspect of the sustainability of ecosystems. The approach to measuring the natural range of variability involves profiling the historic patterns of ecosystem conditions and events. This will require development of appropriate analytical methods and then preparing spatial and non-spatial data to support pathogen, insect, and fire regime analyses. Constructing efficient programs to move data from one step to another in the analyses and finally to the displays will provide techniques suitable for use in many Regions. All ground data and much of the non-ground, supplemental data have been acquired and the interpretations of regimes will be based on existing scientific knowledge.

Activities and Products:

- Development of analytical methods, and collection of spatial and non-spatial data to support pathogen and insect regime analyses; data standards and methods will be developed, tested, and refined; automation of data management; summary and analysis of existing and new data from a variety of sources.
- Evaluation of the process, methods, and precision of the pilot project. A synthesis report an recommendations for improving the process will be produced.

Task 2: Second pilot project

Based on knowledge gained and procedures developed during the first pilot study, a second study will be initiated in another region or ecosystem.

Activities and Products:

- A further refinement of the analytical methods, processes, and standards.
- Validation that the processes will work in multiple ecosystems.
- Evaluation of process, method, and precision of the pilot project.

Task 3: Synthesis, reporting, and technology transfer

Based on the two pilot projects, a handbook will be created documenting the methods, procedures, and data requirements for using current and historic data in defining the natural range of variability of insects, pathogens, and fire in ecosystems.

Activities and Products:

- Handbook for developing an historical perspective on disturbances. This will be a handbook indicating methods and procedures for developing an historical perspective on the role that insects, pathogens, fire, and abiotic disturbances have played in a particular ecosystem.
- Detailed understanding of natural variability in disturbance factors for two pilot Regions.

3.7 Resource Requirements

Table 3.1 displays cost estimates for each of the major areas of activity.

Table 3.1: Resource requirements for the Data and Information Needs Group.

Major Activities and Products	Cost ($1,000)	Duration (years.)
Standardize FPM data collection, management, and analysis procedures	638	5+
Vegetation cover and change detection	1400	5+
Automate anthropogenic and natural disturbance detection procedures	1370	5
Develop data and methods for analyzing pathogen, insect, and fire regimes and interactions at the landscape level	870	5
Total	4278	5

3.8 Discussion

During the process of developing our Mission, Conceptual Model, and Strategy, the Data and Information Needs Group raised a number of key issues and concepts. While these issues and concepts have been carried through the body of the report and incorporated into our objectives and activities, we feel they warrant repeating to ensure that as these efforts move to strategic plan and to implementation, these issues and concepts are not lost.

3.8.1 Cooperation

The development of a national spatial data hierarchy is viewed as a very high priority, but it can not and should not be done by the Forest Service alone. This effort should be undertaken through the Federal Geographic Data Committee (FGDC) and involve all concerned federal agencies, state cooperators, and non-government organizations with an interest in and a need for a national vegetative data layer. It will be through a cooperative effort by all stakeholders in developing this national spatial data hierarchy that true data and information sharing will be possible.

3.8.2 Data Standardization Challenges

Currently, the FGDC is developing national guidelines and standards for spatial data. The Forest Service is integrally involved with this effort, and is charged with constructing the national vegetation data layer. Forest Pest Management (FPM) can help in defining vegetation layer requirements from the perspective of national forest health monitoring and reporting. This would provide input important to nationwide federal standards, which could later help assure uniform data collection and mapping procedures.

Although National Map Accuracy Standards, as developed by the U.S. Geological Survey (USGS), have effectively provided guidance for spatial accuracy, there are currently no existing standards dealing in a similar fashion with the accuracy of attribute data. In an era when geographic information systems (GIS) are being introduced agency-wide to the Forest Service, minimal attribute accuracy should be standardized as well, ideally in the range of 85-90%. The means of testing and displaying attribute accuracy should be clearly defined.

The natural resource community has been using the Anderson Classification of Land Use/Land Cover for over 20 years (Anderson et al., 1976.). The experience gained over this time, and the advent of enormous volumes of remotely sensed data from satellites and airborne camera systems, leads us to recommend revision of the Anderson classification system. The Anderson hierarchical scheme has adequately served past needs, but since the needs have changed new classes should now be considered at each level, and a determination made as to the appropriate level for each classification mapping project. In addition, some thought should be given to melding the Anderson Classification into a higher-level classification of ecosystems (e.g., Bailey's Ecoregions).

Core nation-wide data regarding forest health should be collected to cover predictable agents of change on their minimum repeat cycles. Resources should also be reserved, however, for catastrophic situations which require immediate response, regardless of whether these situations are due to considerations such as higher visibility, political pressure, or natural stressors. Data base design must be rational and realistic; data collection should not be crisis driven. Data collection must support change detection and analysis and, over time, it should aid in the understanding of what level of disturbance is within a natural range of variability.

"Change" must be clearly defined in the context of the causal agent, and the landscape over which it operates. This definition will, in turn, determine the contents of the various data sets and the attribute/spatial/temporal resolution at which they must be constructed. The time period for measuring change will vary with the causal agent, but uniform data collection intervals should be maintained whenever possible.

To promote and ensure data standardization, FPM needs to improve both inter- and intra-agency coordination.

3.8.3 Other Data Issues

Data users within the Forest Service currently face many challenges, challenges that can be expected to multiply rapidly in the future as more data and information become available and are required sooner by decision makers and the public. Clearly the Data and Information Needs Group within FPM will be at the hub of many of these activities. The following list clearly illustrates some of the emerging issues that the Data and Information Needs Group must address in the near future: indicators of social values; data from systematic forest vegetation and stressor sampling programs; data on edge formation; data for linking stand- and tree-level models; landscape-level data; a framework for consistent storage of knowledge and data; meta-data; data security; and data standards.

4.0 Analysis and Modeling

4.1 Challenges

The successful implementation of ecosystem management will greatly increase the managers' need for analytical tools which enable the projection and assessment of consequences of alternative management options. The modeling tools must use indicators of timber and non-timber resource values at a range of spatial and temporal scales. The tools must be able to readily meet a wide range of decision support needs. Their projections must be based on an understanding of forest vegetation dynamics as affected by forest ecosystem processes, including those that involve insects, pathogens, fire, and other disturbance factors. With the increased emphasis on choosing desired future conditions, managers must be able to assess the ecological capabilities of the ecosystems. Landscape-level models of vegetation dynamics that consider ecological processes including succession and disturbances will be used to define the ecologically feasible future conditions as a basis for selecting those that the stakeholders desire.

4.2 Mission

The Analysis and Modeling Group determined their mission to be:

> *To provide managers with analytical models of forest ecosystem processes involving insects, pathogens, fire, and other disturbance factors that can translate the effects of forest management into responses in vegetation-based indicators.*

4.3 Conceptual Model

The basic premise of the Analysis and Modeling Group is that the "kernel" of decision support tools that address ecosystem management decisions will be models that project vegetation dynamics as affected by forest management actions and ecological processes including insects and pathogens, fire, drought, and other disturbances (Figure 4.1). The output of these models must include a set of vegetation-based indicators (e.g., overstory and understory characteristics, vegetation structure and composition). Different models may be required to meet the analytical requirements at multiple spatial and temporal scales. The vegetation-based indicators can in turn contribute to the input of other models and analyses that project changes in indicators of other ecosystem components, e.g., wildlife habitat, water yield, sustainability, or employment.

The primary modeling role, as seen by this group, is the development of forest vegetation dynamics models, specifically where vegetation dynamics are affected by ecological processes involving insects, pathogens, fire and drought. These models are developed in a larger decision support context and their design will thus be influenced by the need to support ecosystem management decisions. These tools must be appropriate for assisting in the choice of desired future conditions, i.e., provide guidance on the expected transition from current to future conditions, as influenced by the processes of vegetation dynamics, succession, and disturbances. The models will

integrate expertise in ecology, entomology, and pathology, related data, and modeling experience to provide scientifically credible tools.

4.4 Strategy

The rapid changes in the USDA Forest Service and endorsement of the ecosystem management approach have resulted in a significant shift in the requirements of decision support tools, including models. Although the Forest Service has developed considerable modeling experience over the past years, many of these models were developed to meet needs other than those currently identified. To meet the mission stated above, the following general strategy has been identified.

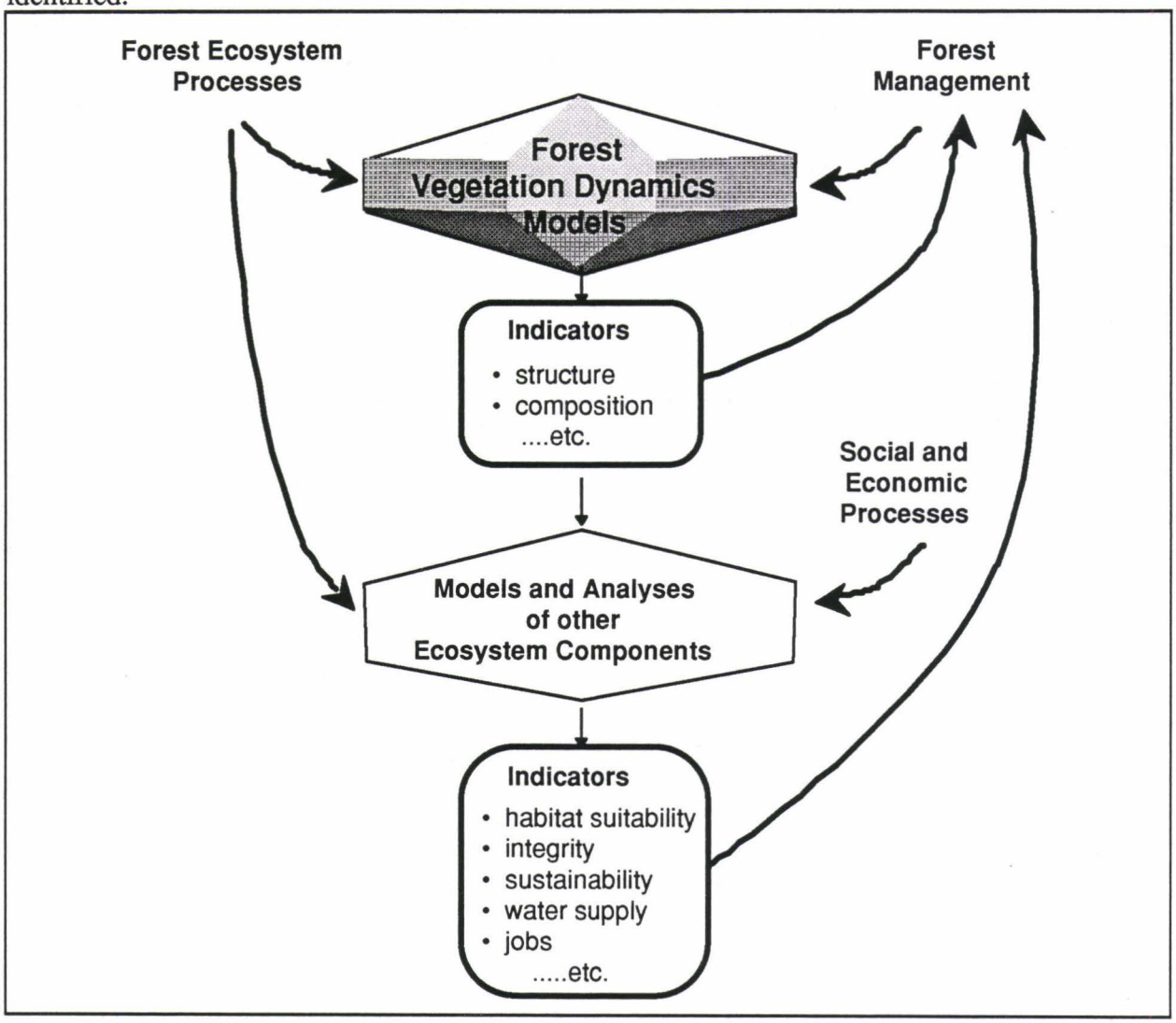

Figure 4.1: Vegetation dynamics models provide projections of changes in vegetation-based indicators, as affected by ecological processes (including insects, pathogens, fire and drought) and forest management actions.

The identification of the new needs for decision support which were discussed at this meeting will be continued. Specific case studies and problem analyses will be used to identify required indicators, spatial and temporal scales, and decision support needs. The ability of existing models to meet these needs will be assessed, and where appropriate, the options for model modifications will be considered. Those models that either currently meet the needs or that can readily be modified to do so should receive continued support in the Forest Service. In addition, it is anticipated that new modeling tools will be required to meet specific needs, most likely in the areas of non-timber value assessment, and analyses over longer temporal scales and larger spatial scales.

This strategy attempts to find a balance between continuing to support modeling tools that are already meeting needs and valuable to forest health assessment and decision support, and developing new tools that are responsive to the new challenges of ecosystem management. Finding this balance, however, will require a careful analysis of new and emerging needs.

Recent developments in hardware and software technologies have created new opportunities for the development of models that operate over larger spatial scales and over longer time horizons. Faster computers with larger storage capacity are available for landscape-level analyses for which data storage and processing needs are greatly increased. Object oriented programming approaches facilitate the development of toolboxes of model components that are readily applied in several DSS environments.

4.5 Objectives

The mission is addressed through three objectives, each of which will be met through a series of activities, described in more detail below:

1. ***Develop or adapt vegetation dynamics models that provide analytical support for choosing desired future conditions among the ecologically feasible alternatives.***

   Primarily, these new models will provide analytical support for choosing desired future conditions, covering spatial scales from landscapes to ecoregions. They will project vegetation dynamics (successional pathways) as affected by non-human disturbances and ecological processes. These models will assist in defining ecological capabilities and in bounding the range of reasonable expectations with respect to the effects of management actions on vegetation-based indicators. These models could also contribute to setting broad priorities for ecosystem restoration and maintenance.

2. ***Take a "fresh look" at existing models, especially those currently supported by FPM/MAG; assess these models' ability to meet emerging decision support needs; and provide maintenance and support for those models that meet the needs.***

   Over the past 10 years, MAG has been instrumental in the development of ten models designed for specific ecosystem types in which vegetation dynamics are affected by various insects and pathogens. Model development has been completed for several of these projects

and is nearing completion for others. The new priorities resulting from ecosystem management have changed the demands for decision support and existing models should be assessed for their ability to meet the new decision support needs. Although a need has been recognized to provide support to the users of existing models, priority should be given to the support and maintenance of those models that are capable of meeting the anticipated expanded needs of ecosystem management.

3. ***Develop analytical support for the assessment of multi-agent (insects, pathogens, fire, drought) impacts on vegetation-based indicators at the landscape scale.***

3a. *Short-term: Combine some of the existing single agent models for specific systems in which agents co-exist.*

In some ecosystem types, single-agent models are not capable of adequately projecting vegetation dynamics because multiple agents are interacting. Therefore development of models that address multi-agent systems has begun, e.g., the Annosus/Bark Beetle model developed in Region 5. The need to provide decision support for specific ecosystem types in which multiple agents are influencing vegetation dynamics has been identified repeatedly, and in the short term, this need can be met by combining single-agent models which have been demonstrated to meet the decision support needs of ecosystem management. Thus, an immediate decision support need can be satisfied by building on current modeling expertise and existing tools. Combined single-agent models will only be developed for selected systems.

3b. *Mid-term: Develop models which include multi-agent effects on vegetation structure and composition at the landscape-level.*

This mid-term activity will develop a process and analytical framework that will eventually lead toward the comprehensive coverage of those ecosystem types for which decision support tools are required. The anticipated model(s) of vegetation-dynamics are based on a 'vegetation-centered" approach that simulates the effects of a range of ecological processes and agents of change on vegetation-based indicators. The choice of initial ecosystems will be made with the framework development in mind and will address many of the indicators required for ecosystem management.

4.6 Major Activities and Products

Develop or adapt vegetation dynamics models that provide analytical support for choosing desired future conditions among the ecologically feasible alternatives.

A major shift in the paradigm for developing management plans for the National Forests has occurred. Under the previous planning process, analyses evaluated specific schedules of management activities appropriate for achieving a desired future condition and meeting commodity production objectives. This form of analysis is being replaced by comparison of alternative

descriptions of future conditions and better understanding the ways management activities can mimic natural disturbances. The desired future conditions will be defined over broad geographic areas and will emphasize broad indicators of vegetation structure and composition as well as interpretations of sustainability and resilience.

To meet the decision support needs of this new planning paradigm, models will be required that project vegetation dynamics over time (succession), as influenced by ecological processes, insects, pathogens, fire, and forest management activities. The purpose of these models will be to assess ecological capabilities, i.e., to define the ecologically feasible future conditions as a basis for selecting those that the stakeholders desire.

The long-term goal of this activity is to develop models for a wide range of ecosystems in the US. The specific purposes of the activities are:

1. to develop a prototype model framework that addresses the new needs in a specific ecosystem type;
2. to record and evaluate the development process as input for subsequent implementations of the model; and
3. to implement the model in several case studies in additional ecosystem types.

The project will be initiated by choosing an initial ecosystem for the development of the pilot model. This ecosystem should combine both a set of problems (e.g., fish-forestry interactions or rangeland and biodiversity issues) and indicators that are sufficiently broad and interesting that the pilot model will be applicable to a wide range of users. The model development process will follow the approach that has been implemented successfully in the past. After defining the problem(s), the indicators required in the decision making process will be identified. For example, indicators for vegetation could be successional stage within broad habitat groups and broad classes of stand density and/or volume. One necessary activity in the process will be to translate abstract concepts, such as ecosystem viability, sustainability, and resilience, into quantifiable measures that will be derived in the analytical framework. This translation procedure should be coordinated with the procedures addressed by the Value Determination Group. It is a prerequisite, however, that abstract concepts are quantifiable if the models are to provide indicators for these concepts.

The ecological processes affecting the indicators will be determined. The scope of the ecosystem simulation will in turn be determined by those processes. During this bounding exercise, the processes internal to the system will be distinguished from external influences.

Existing tools and models will be reviewed and their ability to contribute to the analysis of vegetation dynamics will be evaluated. Where possible, existing tools will be used or modified for use in the analytical framework. The group anticipated, however, that a fundamental rethinking of the modeling approach and significant new model developments will be required to meet the needs of the new planning paradigm. Using a "rapid prototyping" approach to model development will yield a prototype working model by the end of Phase 1, and a fully implemented pilot case study by the end of Phase 2.

After completion of the prototype, additional case studies will be selected and starting in Phase 3, the model will be transferred to other ecosystem types. The experience gained during the implementation of the pilot case study and the tools developed in the process will ensure that the time and resources required for subsequent implementations will be significantly reduced.

Activities and Products:

- Phase 1. Prototype working model for one ecosystem type.
- Phase 2. Model fully implemented and tested for pilot case study, and implementation in additional case studies in progress.
- Phase 3. Report on the development process, including an evaluation of the approach, assessment of the data sources, user feedback, and recommendations for the implementation in additional ecosystem types.

Review current models; support and maintenance services.

Task 1: Review of current models.

The introduction of the new ecosystem management paradigm into the USDA Forest Service decision making and planning processes has resulted in a significant shift and expansion of the indicators that need to be considered. The Analysis and Modeling Group decided that a review of the modeling work completed and in progress at MAG is appropriate given the recent changes in decision support needs. The objective of this review is to establish to which extent the existing models, most of which were developed during a time of different needs for indicators, are able to meet the new and emerging requirements.

The review should, at a minimum, address the following issues:

1. What are the indicators and actions at the ecological land unit (ELU) level that will be required in the future?
2. Which ecological processes need to be included in the models to predict the indicators identified in 1?
3. To what extent are the existing models meeting the needs identified in 1 and 2?
4. Solicit feedback from the user groups on issues related to the models' ability to meet their planning and decision support needs. This must include an assessment of the output and indicators generated by the models, an assessment of the ease of use, the data requirements of the models, and the models' hardware and software requirements.
5. Solicit feedback from user groups of the existing models, on issues related to service, e.g., technology transfer processes, training materials, and technical support.
6. Solicit feedback from users and developers about the process employed in model development.

The workshop participants recommend that the review be conducted by an experienced third party not affiliated with any of the current model development teams. Given the complexity of the scientific and technical issues that will be addressed in the review, considerable attention must be paid to the selection of the reviewer(s) and they must be encouraged to interview various user groups, model developers, and support groups, including FPM/MAG.

Table 4.1: List of models currently supported or under development by FPM/MAG. C=complete, ß=in testing stage

Western Root Disease	C
Annosus/Bark Beetle	ß
Douglas-fir Tussoc Moth	C
Western Spruce Budworm	C
Douglas-fir Beetle	C
Lodgepole Pine/Mountain Pine Beetle	C
Dwarf Mistletoe	C
White Pine Blister Rust	ß
West-wide Pine Beetle	ß
Jack-Pine Budworm	ß

Activities and Products:

- A detailed written report summarizing results of the review process should be prepared as soon as possible. The report will describe the process employed in the review, the results and findings, and list recommendations for future model development and support activities.

Task 2: Support Services: Maintenance

The insect and pathogen models for various geographic areas are linked to the Forest Vegetation Simulator. The dynamic nature of these models and new scientific findings make it incumbent to periodically update the model parameterizations or the model code. The 615 procurement will necessitate a transition to a new computer platform used throughout the Forest Service. This transition will be a slow process with full implementation requiring several years. Those models that meet current users needs must therefore be available for continuing efforts on both the current and the 615-designated platform. In addition to the Forest Service user group, there has been a growing interest in the accessibility of the models by other agencies, state and private entities, and universities. The Forest Service has responsibility for forest management beyond the boundaries of National Forest System lands. State & Private Forestry should take leadership toward ecosystem management across jurisdictional ownership boundaries. This leadership role would be supported by fostering the access to ecosystem management models. The common model platform has been the PC, although other platforms such as IBM-mainframes are also used. The accessibility and distribution of the models needs to improve to accommodate growing needs. Specific model maintenance activities include:

1. Cooperation between the Washington Office Forest Management Service Center and FPM/MAG for revisions and updates. Bulletin distribution to Regional coordinators of all updates.
2. Availability of models with an established distribution process and support system on the Data General, PC, and Unix platforms (and once designated, the 615 platform).
3. A user support and user feedback line, and evaluation of and response to feedback from the user community.

Activities and Products:

- Up-to-date insect and pathogen model extensions linked to the Forest Vegetation Simulator on multiple platforms with various levels of technical support available through phone, e-mail, or personal assistance. Support of other models developed during the 5-year period covered by this task force report.

Task 3: Support Services: Transfer and Training

This task addresses the importance of providing adequate training and technology transfer after model development has been completed. The ultimate "success" of a model is measured in part by the number of satisfied users. In each Region, the involvement with the models is relative to the Region's need for decision making tools (e.g., Forest Planning, EIS, etc.). The use of these tools requires that some analysts be trained in each Region and that assistance is provided after the initial training. Training material will be developed for each completed model and training will be provided for those models that appear to meet the planning needs, as measured in model use and user-demand for assistance. Specific technology transfer and training activities include:

1. Upon request, training sessions for Regions (in cooperation with the local Forest Pest Management staff). This approach to technology transfer has been successfully applied in the past.
2. Development of documentation and visuals to assist individuals interested in using the models. Development of training materials in the form of overheads, slides, and training manuals.
3. Brochures, newsletters, or bulletins to describe modeling activities and the products currently supported.

Activities and Products:

- Training sessions provided in cooperation with the Regions to meet their modeling needs. Documentation and presentation materials to assist in training efforts.

Task 4: Support Services: Model Invalidation and Sensitivity Analyses

Upon completion, the ecosystem models represent the "state of the art" and reflect the data and scientific understanding available at the time of their development. Models that are used to support the decision making process must remain current with regard to the evolving scientific understanding of ecosystem dynamics. One component of model support services therefore is to monitor the models' ability to project ecosystem dynamics in the full range of model application. As data become available from the application of the models in new systems, the model projections

have to be tested against available data, or where lacking, expert judgement. Following the Adaptive Management approach to model development, invalidation efforts and sensitivity analyses will be conducted as data become available for new ecosystem types. The results of these analyses will be archived and contribute to the record of model testing and behavior analyses. If required, assistance will be provided to Regions and Research to periodically modify and update models.

The following activities will ensure that models employed by the user community are up-to-date:

1. Statisticians, including those at MAG, should continue to cooperate with Regional entomologists and pathologists, by testing model projections against field data as they become available. Model (in)validation will thus be an ongoing process, to ensure that models are current relative to the evolving scientific understanding.
2. A record of model tests, sensitivity analyses, and projections will be maintained such that new users can review whether they are intending to apply the model to ecosystem types or management regimes that have not previously been tested.

Activities and Products:

- Reports on sensitivity analyses, model (in)validation, and model application to specific ecosystem types.

Task 5: Support Services: Database Administration

As a result of the Pest Trend Impact Plots (PTIPS) Technical Development Project, a database containing data from permanent plot surveys has been designed for the purpose of invalidation of models. Database administration and technical support are necessary for the Regions' continued use. Conversion programs for loading survey data into the database structure and reports for analysis of the data will be developed during the next 5 years.

1. Working cooperatively with the user group to reach the goals of this task force report;
2. Annual training sessions and database review workshops; and
3. Modifications to the interface and enhancement of the error checking capabilities.

Activities and Products:

- Technical support and assistance to the Regions for database maintenance. Development of loader programs and various reports. Operational database on both the 615 and DG platforms.
- Conversion programs for new insects and pathogens introduced to the database.
- Database and all associated programs will be operational on the 615 platform.

Task 6: Suppose... Framework

The Forest Vegetation Simulator and its model extensions of insects and pathogens, although much used in management analyses by staff of the National Forests, require considerable experience with the system. Analysts must understand how to use the keywords for specifying the scope of the simulation, how to use the systems for storing resource data, and how to link the output with

systems for visualizing the results of the simulations. In many cases, the full capabilities of the system to analyze management options are not used effectively, and the number of advanced model users is limited.

To increase the accessibility of the models, a Windows-based graphical user interface, called Suppose..., is being developed. This system will permit efficient analyses of management options at landscape levels as well as the traditional stand simulations. The system has components for describing the geographical scope of the analysis, for defining proposed management activities in the conventional jargon of silviculturists and pest managers, for accessing resource data bases, and for generating user-defined displays of indicators.

Four agencies are cooperating in this activity:

1. Forest Pest Management, Methods Application Group;
2. Timber Management Division, Forest Management Service Center;
3. Intermountain Research Station, Quantitative Analysis Research Work Unit; and
4. British Columbia Ministry of Forests, Inventory Branch.

Activities and Products:

- A Windows-based graphical user interface will be available on multiple platforms to simplify use of the Forest Vegetation Simulator and to increase the user base.

Develop analytical support for the assessment of multi-agent (insect, pathogens, fire, drought) effects on vegetation-based indicators at the landscape scale

Task 1: Combined models of single agents

Early development of the insect and pathogen model extensions represented the effects of single damaging agents on stand development. As the process of model development became more sophisticated, later models, although representing only the dynamics of a single agent, also included static representations of other agents. For example, the western root disease model included interactions with windthrow and three types of bark beetles represented by exogenous variables. In parallel with this progress toward recognizing the complex nature of multiple agents, there has been a trend toward seeking commonalities of model structure for classes of agents. For example, the western root disease model, which itself was parameterized for both *Armillaria* and *Phellinus* and their interaction with several bark beetles, served as a template for the Annosus/Bark Beetle model developed for Region 5. Likewise, the model of mountain pine beetle in lodgepole pine was superseded by a model of three species of bark beetles affecting five species of pine.

The next step in this evolution is to model the dynamic interactions between several agents that may interact in the same land unit. Figure 1 of the report *Towards a forest ecosystem modeling framework: a strategic plan for developing multiple pest models* (Sutherland et al., 1993) lists the regions and agents where dynamic interactions occur. The need for multi-agent models is particularly critical when the interactions are synergistic.

In the short term, and for a limited set of ecosystems in which vegetation dynamics are affected by specific agents, it appears that the most efficient approach to properly represent interactions between important agents is to combine the appropriate existing single-agent models. This process has been initiated successfully, as described above. This approach builds immediately on past experience gained with single agent models at both the stand and landscape-level of modeling. While this approach promises to deliver intermediate solutions to immediate problems, it is presently assumed that the combined single-agent models will not suffice to meet the ecosystem management decision support needs for the full range of ecosystem types.

Activities and Products:

- Combine single agent models, where appropriate, to simulate the effects of multiple agents on vegetation-based indicators as an interim step to meeting current decision support needs.

Task 2: Multi-agent Model

The shift in decision support needs, associated with the ecosystem management approach, has an impact on the types of projections required from forest vegetation dynamics models. The emphasis on the scheduling of management activities has been replaced by an increased need to assist in the biologically and ecologically realistic choice of desired future conditions. The new models will be employed in site-specific landscape and project-level analyses. These new applications require very different kinds of models: their primary purpose is to evaluate whether the desired future condition **can** be achieved given the present state of the forest and vegetation dynamics. At this scale of modeling, the activities to be represented must be described in much more general terms than in the management models used previously, but the representation of ecological processes must be comprehensive enough to project vegetation dynamics as affected by insects, pathogens, fire, and drought.

Recent advances in our understanding of the role of insects and pathogens in ecosystem function suggest that effects of many agent complexes should be modeled with greater emphasis on the relation of vegetation to the site's carrying capacity. Tree stress indicators can be used to project the effects of multiple agents without specific representation of their population levels. Models operating at this level of resolution would include broad classes of damaging agents rather than individual species.

To evaluate how effective such a model can be in supporting decisions at this level, the first issue to be resolved is the coice of an ecosystem. The location should be both ecologically complex, so as to challenge the concept, and useful for evaluating real decisions for the chosen area. Through a workshop format, the scope of the model will be defined by following a sequence of steps to elicit information from the managers of the area and the technical specialists knowledgeable about the selected ecosystem. Although these steps repeat the steps described for attaining the first objective, the information elicited will be very different because a very different decision space is being considered.

The steps are:

1. identify the general ecosystem type modeled,
2. identify management actions,
3. identify *end-point indicators* of *ecosystem values*,
4. identify the *temporal context* (horizon & resolution),
5. identify the *spatial context* (horizon & resolution),
6. identify primary *ecosystem components*,
7. identify the critical *interactions between components*, and
8. assemble model representing effects of the management actions on the indicators.

Activities and Products:

- This activity will generate a model scaled to landscape-level decisions that represents the aggregate effects of the full spectrum of insects and pathogens as they are influenced by specific management activities.

4.7 Resource Requirements

Table 4.2: Estimated resource requirements for the Analysis and Modeling Group.

Major Activities and Products	Cost ($1,000)	Duration (years)
Models to support choice of desired future conditions at the landscape level for USDA FS planning process	960	5
Review of needs, model support and maintenance services	2,875	5
Combining single-agent models	380	2
Develop multi-agent models	1,930	4
Total	6,145	5

The budget in Table 4.2 assumes that money and staff positions are fully interchangeable. The estimates of full-time equivalents (FTEs) have been converted to resource requirements assuming a total cost of $70,000 per FTE. The budget estimates are not corrected for inflation.

5.0 Information Display

5.1 Challenge

Forest ecosystem management requires managers to interact meaningfully with a large and diverse group of stakeholders to achieve consensus in choosing among a wide array of complex possible futures. Each alternative future provides a different mix of benefits and costs, each having variable levels of uncertainty in achieving their projected outcomes. Means are required to expand access to the decision making process to include a broad cross section of the public and other stakeholders. It is essential that relevant stakeholders have adequate information about and understanding of the consequences of alternative management options. It is equally important that the desires and concerns of all stakeholders are effectively represented in the ecosystem management and decision making process.

5.2 Mission

The Information Display Group determined their mission to be:

> *To create a plan which addresses increasing public need for information on forest ecosystem issues by providing affordable, flexible forest information display tools and to ensure that data visualization will be as available and useable as word processing.*

5.3 Conceptual Model

The information that is required by forest ecosystem management is both broad and extensive. The Information Display systems serve to transform multiple outputs from the Values, Data, Models, and Decision Support components to a visual format more comprehensible to the user (Figure. 5.1).

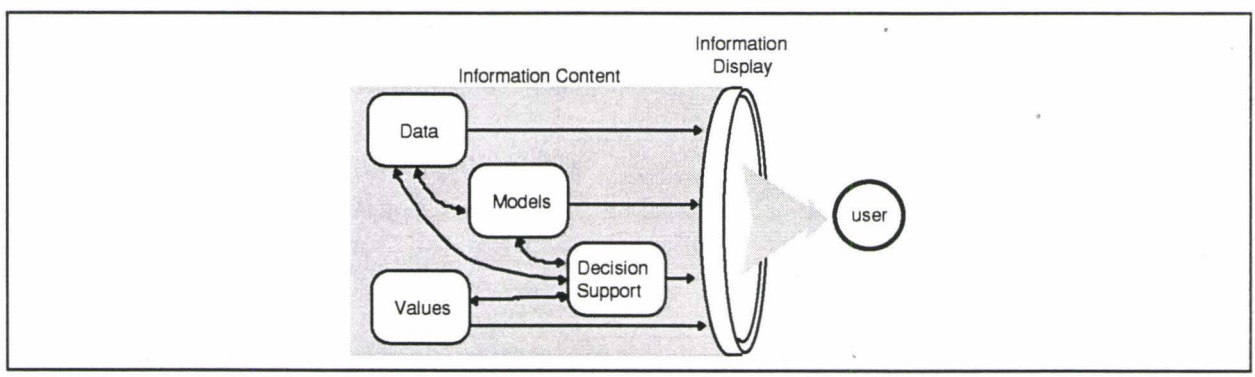

Figure 5.1: Conceptual model of the relationship among Challenge/Technology areas from an information display perspective.

Visual displays capitalize on the sophisticated information processing capabilities that are embedded in the human perceptual and cognitive systems. Comprehension of information that is complex, comprises patterns over space and time, and is context sensitive is enhanced through visual display. This does not imply that all users will require a visual interface, or that all information must pass through this interface. However, a key value of visual information displays is the capacity to carry communications between groups where types and levels of background knowledge may be quite different.

5.4 Strategy

The strategy for the development of the Information Display system was based on the assumption that it would serve as a direct user interface. This requires a review of who will use the displays and the nature of the information to be communicated. The fundamental question of why visual displays should be used was also addressed; we identified what visual displays can achieve beyond other formats of display. Since visual displays should not be perceived as a panacea, we discussed specific attributes of information displays that determine their effectiveness. Finally we recognized that the strategy must include a consideration of how the new technology will be adopted.

To develop our recommendations we identified the forest manager as the key user of visual information display. It is critical, however, to see the forest manager as just one in a range of potential users, and to see users as both information display producers and consumers. The range of these groups will include, but is not limited to, the following:

- **The Resource Scientist**, works at the most abstract level, and uses visualization to reveal otherwise unseen information relationships. The scientist communicates most frequently with resource specialists but increasingly with other user groups.

- **The Resource Specialist**, works more concretely to create real world solutions, and communicates with scientists and other specialists as well as general public stakeholders.

- **The Resource Manager**, integrates data to develop problem solutions. Communication occurs both internally with resource specialists and externally with general public and special interest groups.

- **The General Public**, increasingly demands education and information to assist in decision making and understanding their own position. While traditionally visual displays have been used to communicate with this group, in the future visual tools might be used to enable the public to "play out" alternative resource scenarios.

- **Political Interest Groups**, who may be resistant to resource policies, might benefit by more transparent access to resource data and model predictions. Visual display systems would enable this group to experiment with alternative solutions and their ramifications.

The types and formats of ecosystem information is broad and diverse, so information displays will be designed to:

- make data comprehensible to a more complete range of users, from specialists to general public
- display data at various levels of visual realism
- access and navigate increasingly large and complex databases
- enable experimentation with ecosystem relationships via a visual interface
- display and navigate data at both broad and fine scales
- present fine scale data in the context of broad geographical areas and long time horizons
- explore the spatial and temporal consequences of change and the rate of change
- reveal the completeness and quality of data
- communicate the uncertainty of model predictions
- bridge between social and biological data; display values data simultaneously with visible ecosystem components

To accomplish all these communication and information use objectives, the types of data that will be displayed will include:

- a range of alternative model scenarios and data streams that include historical, current, and projected components
- stochastic, multi-variate information
- distributions of components and attributes in both the spatial and temporal dimensions
- ecosystem structure, composition and function, and social indicators, including values
- metadata— descriptors of data quality, completeness, and source

The visual display of information has largely been developed on an ad hoc basis, with a developing vocabulary of presentation formats that are understood by the users trained in particular domains (e.g., nomograms communicate complex information well, but only if the viewer is trained in their interpretation). In order to ensure that the visual displays are understood by all the users, an evaluation process is required. Furthermore, for realistic visual displays, the viewer makes an interpretation that is perceived as significant (in the sense that it leads to value judgments, opinions, and action). Little work has been done, however, to determine what the viewer actually perceives, and what attributes of the display are influencing the perception and interpretation.

Consequently, work is required to develop an understanding about:

- the reliability and validity of various visual data display techniques
- the kinds of display techniques most suited to different audiences and decision settings
- the necessary or sufficient complexity of different display techniques for a range of decision settings.

The mission of the Information Display Group dictates that the tools of visual communication be made pervasive throughout FPM, the Forest Service more generally, as well as other environmental management agencies. Furthermore, the intent of visual display is to involve new groups of users in informed discussion of ecosystem health issues. Among others, the Forest

Service needs to communicate the effects of disturbances to a wider range of stakeholders. This communication challenge requires that visual displays be broadly adopted.

New technologies, such as visual displays, are not always adopted simply because they are there. The user must be aware of the technology, and must be convinced that the benefits **to the user** are worth the effort of making a change, before the technology is adopted, or even tested.

Some approaches to ensuring the adoption of visual display tools were discussed:

- address the needs of non-computer specialists as well as computer users, the users of the tools as well as the audiences for the information
- engage in technology marketing
- use pilot programs to demonstrate the values of the technology
- implementation through the Information Management Framework (IMF)
- facilitating integration with other information management initiatives.

In summary, the strategic plan for the development of the Information Display system is to create and maintain a suite of information display tools suitable for communicating ecosystem values, structure, composition, and function to potential users. To support this development an investigative program will assess the effectiveness of information display tools in communicating the intended information, and explicit efforts will be made to help insure the adoption of visual display tools.

5.5 Objectives

The information display system development strategy will be achieved by meeting the following six objectives:

1. Evaluate user response to alternative information display systems

A program is needed to investigate systematically user responses to different image display formats. The results of this evaluation will provide guidance for the development of effective visual displays.

2. Provide a common interface for visual display tools

Menu or windows based software will present a common interface that allows users to access the array of visual tools. It will support integration as well as the import and export of data among visual tools, and function as a processor for visual displays much as word processors function for text.

3. Develop an interactive visual simulator

An interactive 3-D forest ecosystem environment simulator will realistically portray inventory data and model output at multiple scales in real time. It will provide the user with an

instrument panel that displays forest conditions, values and management actions. It also provides an audit trail of user actions to investigate human interaction with the environment.

4. Provide a visual conceptual model for easy exploration of local ecosystem conditions

This tool will provide templates for ecosystem dynamics based on commercially available modeling tools. The templates for ecosystem dynamics (e.g., vegetation, fire, wildlife, other biotic and abiotic factors, etc.) will allow the user to quickly create prototype models to reflect local conditions.

5. Provide an image filing and retrieval system

A computer image filing and retrieval system (based on the Info Center concept) will provide access to a database of images, and will organize and catalogue an expandable distributed library of visual material. Access will be similar to Mosaic, with a FS homepage.

6. Develop interactive environmental educational software to enable better understanding of forest ecosystem management concerns

This program will allow users to explore changes in ecosystem attributes and evaluate trade-offs based on user selected options. It will serve to deepen the understanding of issues so that managers, the public and other stakeholders can more effectively interact and participate in making informed choices.

5.6 Major Products and Activities

With the exception of objective 1, each of the objectives listed above will be met by the development of a coordinated set of information display software packages. Each software system will be developed following the Software Development Life Cycle: scope, specify requirements, design, prototype, alpha test, beta test, train, produce, sustain and maintain, sunset. The activities and the characteristics of the software systems designed to meet each objective are briefly described below.

Objective 1. Evaluate user response to alternative information display systems

This program will investigate user responses to different visual display formats. Program results will provide guidance for the development of effective visual displays. Field studies will provide information on how subjects respond to existing and innovative display formats, including those to be developed under the following objectives.

Objective 2. Provide a common interface for visual display tools

A *Forest Viewer Shell* will be developed to serve as the common link between an array of modules that will allow users to access information for specific reporting purposes. The interface will be consistent throughout the agency and will allow the integration of modules as they are

developed. The shell will facilitate the exchange of data inputs and outputs and visual information such as charts, graphs, animation sequences, and photographs generated by the various modules.

Objective 3. Develop an interactive visual simulator

The *SmartForest Module* will be developed as an interactive 3-D forest ecosystem environment simulator. It will realistically portray inventory data and model output at multiple scales in real time. It will provide the user with an instrument panel displaying forest conditions, values and management actions. Through the panel, the user can construct, investigate, adapt and modify scenarios by moving through the 3-D environment and querying for specific information on components. It will allow the recording of an audit trail of user actions which will assist in investigating human interaction with the (display) environment.

Objective 4. Provide a visual conceptual model for easy exploration of local ecosystem conditions

The *Scenario Sketchpad* will provide templates for ecosystem dynamics based on commercially available modeling. The templates are analogous to a conceptual model of an ecosystem. For instance, one template could represent the dynamics of a forest pest such as bark beetle including the components of the ecosystem affected by the disturbance and the links between those components. Once the template is assembled, the user can adjust the linkages and characteristics of the components to address issues specific to local conditions. Experimental scenarios played out through the templates would serve as a pre-cursor to more detailed modeling.

Objective 5. Provide an image filing and retrieval system

A computer image filing and retrieval system based on the Info Center concept will provide access to a database of images. The *ImageNet* will organize and catalogue an expandable distributed library of visual material. Collections consist of materials that characterize a range of conditions such as fuel loading, pest hazard, and levels of disturbance agents.

Objective 6 Develop interactive environmental educational software to enable better understanding of forest ecosystem management concerns

ForestFutures will be a graphically driven exploration of general ecosystem relationships. The user will be able to interactively observe the dynamic quality of these relationships and the consequences and trade-offs generated by their interaction with the processes. The software would be designed for use in training managers and resource professionals, as well as in other educational environments such as public meetings, visitor centers, and schools.

The software systems listed above are related to each other in a logical framework as described in Figure 5.2. The Forest Viewer Shell is a generic interface that allows users to access a number of modules that will be developed under this strategic plan as well as visual materials from other sources. Three modules within this shell are proposed: *SmartForest,* the *Scenario Sketch Pad,* and *Image Net.* A publicly accessible educational software package, *ForestFutures*, will be informed by the models and data within the entire information display system. In order to guide the

initial development of each system, and to ensure that each visual display system is effective, a continuing program of systematic evaluation will test user perceptions and interpretations.

5.7 Resource Requirements

The resource requirements for information display total approximately $3 million over a five year period. Resource estimates and time requirements are estimated for each major product and activity in Table 5.1. Most of the work is expected to be subcontracted. The estimates do not include administrative overhead or salaries for Forest Service staffs. An inflation allowance of 10% per year has been included.

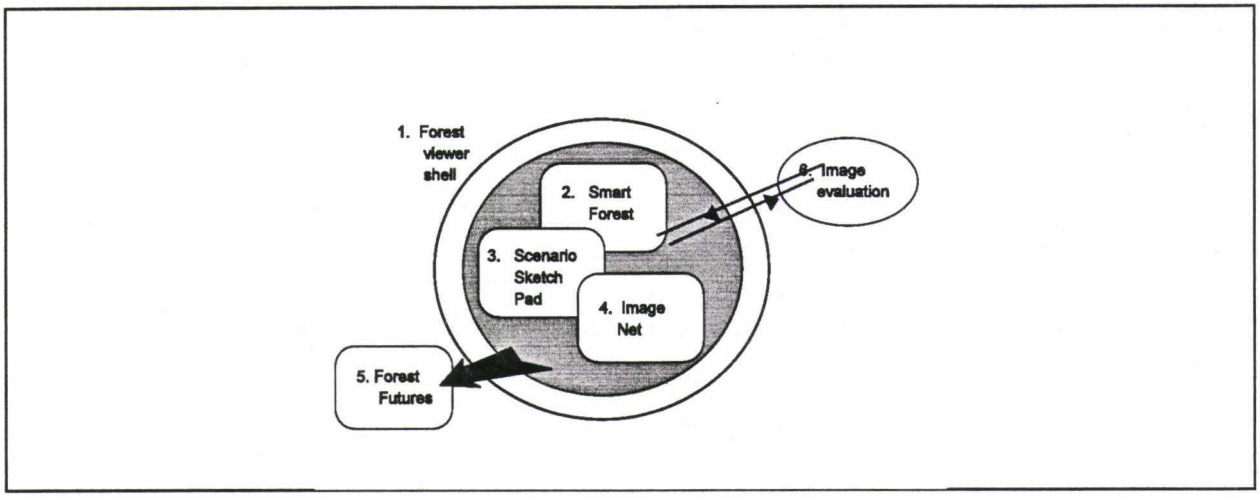

Figure 5.2: Relationship between the tasks proposed for information display.

Table 5.1: Resource requirements for the development of the Information Display System

Major Activities and Products		Cost ($1,000)	Duration (years)
5.1	Evaluation of user perceptions and interpretations	609	3
5.2	Develop common user interface (*Forest Viewer Shell*)	322	3
5.3	Develop interactive visual simulator (*SmartForest*)	1,299	3
5.4	Develop ecosystem visual conceptual model (*Scenario Sketch Pad*)	439	2
5.5	Develop image filing and retrieval system (*Image Net*)	285	2
5.6	Develop interactive forest ecosystem educational simulator (*ForestFutures*)	90	1
	Total	3,044	

5.8 Discussion

During the workshop a number of issues were discussed that relate to the successful development and implementation of visual displays. As for most areas of publicly funded projects, resource limitations were noted. This refers not only to the lack of funds, but also to the availability of qualified people to do the work. Concerns that were deemed particularly significant are discussed below.

5.8.1 Nature of Displays

The people, information, and circumstances of use will certainly continue to be diverse. Communication tools are most effective when designed for the appropriate audience, content, and context. Clearly there is a need for an array of tools that range from simple graphics to comprehensive systems that include realistic representations. Furthermore, it is to be expected that different users will have different operating platforms, hence the tools should be designed to be transferable between platforms.

If the display tools are to be readily accepted and used, they must be simple, portable, and work quickly. Since the different uses demand an array of tools, it is also imperative that these be perceived as a seamless continuum.

5.8.2 Adoption

Public access to new technology and interest in ecosystem management issues will force the Forest Service to accelerate the adoption of information display tools. The agency is not renowned for being on the leading edge of technologies. As in any large institution, there is resistance to acquiring new technologies, including computer hardware and software. In a large organization it is costly to make frequent changes, and it is also difficult to coordinate activities if the technologies among subgroups vary greatly. This situation is further exacerbated by the rapid development of computer-based technologies.

Acceptance of new technology usually comes from the bottom up. Management often does not understand the value of the technology, and is thus resistant to change. Thus the technology should be perceived as useful and cost effective at the district level. This perception requires an initial awareness of the existence of the tools, backed by word of mouth sharing of the benefits of the technology. Initial awareness could be communicated through a newsletter or e-mail announcements.

There is particular resistance to information display technologies. These are often not regarded as necessary, but rather as "pretty pictures" that are not seen as "scientific". The value of communicating complex information is difficult to quantify.

5.8.3 Data Concerns

One of the critical issues identified by the Information Display Group is the incompleteness of the data. Visual display of information dramatically exposes gaps in data. Ecosystem data is necessarily incomplete; a complete data set would imply an impossible level of detail and extent. Data has been collected where it is thought to be required, and this is patchy in content, space, and time. The lacks can be meliorated through a better data coordination system (see Data and Information Needs Group) and through the incorporation of data from sources outside the Forest Service and the Federal agencies. Where data is patchy, and the visualization techniques require a seamless presentation, interpolation techniques will have to be developed and validated.

5.8.4 Support

The second critical issue raised by the Information Display Group is the question of how the implementation and use of new technologies will be supported. In the past, projects have been supported only while they are under development. Project support has been highly dependent on the commitment of the people involved, and we cannot expect these individuals to be present for the entire life of a project. It would take a large level of effort to fully support the life span of the technologies, and this effort is best coordinated with other elements of the Forest Service.

Most of the technologies to be developed for information display are more widely applicable than Forest Pest Management, or even the Forest Service as a whole. In preparing the information display development plan we have assumed that support for specific line items (software systems and activities) will be included in the budget during the development phase, but that delivery and ongoing user support will be provided in some other form, outside the scope of this plan.

6.0 Decision Support System

6.1 Challenge

Public land managers must make complex decisions in a "fish bowl" environment in strict compliance with a complex system of policies, laws, and regulations. The process of pre-decision analysis involves many stakeholders. These stakeholders represent a wide variety of knowledge and perceptions about management objectives and acceptable methods of achieving them. Ecosystem management requires the ability to assemble unprecedented quantities of textual, tabular, and geographic data needed to drive a suite of interrelated biophysical and socioeconomic models. Negotiation and discussion among stakeholders requires easy access to and clear presentation of data and information to facilitate comprehension of complex data and concepts.

The move toward ecosystem management has significant implications for the complexity of the decision making environment. In particular, the shift to an ecosystem management perspective in decision making will require that the information provided to participants in the decision making process must:

- deal with a broad set of indicators reflecting an expanded set of ecosystem values and scales (both social and ecological)
- deal with indicators at multiple-spatial and temporal scales
- be meaningful to and understood by an expanded set of participant
- make it easy to access, compare, and evaluate the effects of possible alternative management strategies.

For ecosystem management to improve over time it will be critical that new knowledge and understanding that will be gained from monitoring the implemented management strategies can be effectively incorporated in future decision making. The information available to the decision makers and the decision rationale must therefore be clearly documented. The format and content of such documentation must facilitate both its generation and use.

Decision support tools and integrated decision support systems must provide:

- access to data and knowledge
- ability to use proven analytical tools (models)
- ability to analyze data through personal or ad hoc model generation
- utilities to generate a variety of displays which depict information relevant to different perspectives
- sound support for comparison across alternative actions and potential futures (this constitutes support of the decision point, not just for pre-decision analysis)
- ability to generate integrated documentation for a variety of media
- access to simple and sophisticated spreadsheet tools for flexible and familiar analytical support
- automatic means of recording important analysis steps and lineage of base and derived data

- expression of levels of certainty associated with data and analyses

6.2 Mission

The Decision Support Group determined their mission to be:

To create a plan which provides forest health information (data, knowledge, and analytical tools) to support the decision-making process for ecosystem management. To do this by:

1. *Providing information management capabilities that incorporate information on forest health, change agents, and their roles in ecosystems.*

2. *Providing a decision support environment that facilitates communication and learning among stakeholders involved in the ecosystem management.*

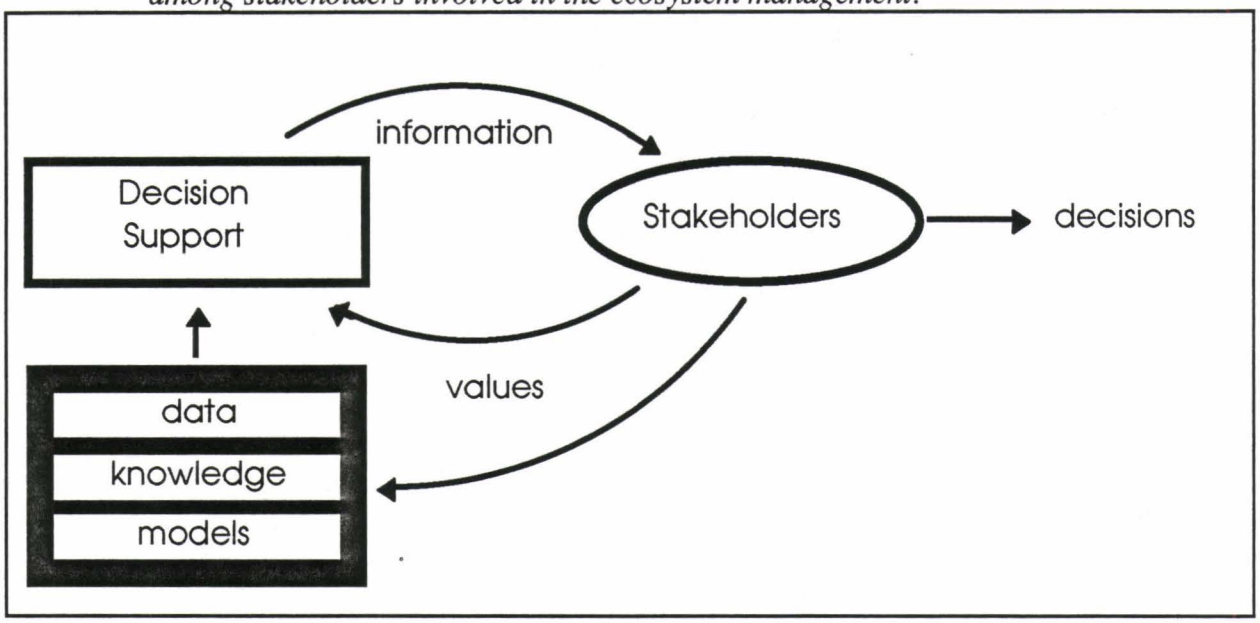

Figure 6.1: Decison support for ecosystem management brings data and knowledge to stakeholders and enables stakeholders to bring their values, data, and knowledge to the decision process.

6.3 Conceptual Model

Stakeholders must have access to decision support systems which enable open dialogue among interested parties. Open dialogue requires that data and information be expressed in a variety of ways so that many views or perspectives can relate to basic and derived data as well as to methods of analyzing these data. Open dialogue requires support for ensuring the level of credibility of data and analytical techniques can be understood by all parties and is recorded as part of the decision record.

We believe it is infeasible to construct a single Decision Support System that would contain all data and projection models for all ecoregions. We suspect a single system is even undesirable because we must deal with a diversity of ecosystems, the state of science in ecosystem modeling and management is not fully mature, and our social and political environment is very dynamic. We believe a wise approach is to add value to data in order to enhance comprehension by diverse stakeholders. We plan to develop a comprehensive framework for the integration of data and analytical support in order to enable teams of stakeholders to conduct integrated analyses across subject specialities, and to support the comparison of alternative actions and potential outcomes through sound decision support. It is important that a framework for integrating data, knowledge, and decision analysis provide open avenues for adaptation to specific ecoregions. Several aspects of the current development environment support this type of approach:

1. ecosystem management will of necessity occur in the short term regardless of the availability of the necessary DSS - a modular approach will allow new tools and techniques to be applied in the short term without the need to wait for the *"ultimate system"* to be developed,

2. a modular approach should facilitate the development of multiple tools/DSS components in parallel by independent development teams while still providing for the future delivery of integrated easy-to-use DSS, and

3. the overall scope and requirements for integrated DSS for ecosystem management are beyond the mandate of any single group. By adopting and supporting a strategy of developing modular systems the partners can individually and cooperatively develop components which reflect their unique expertise and perspective.

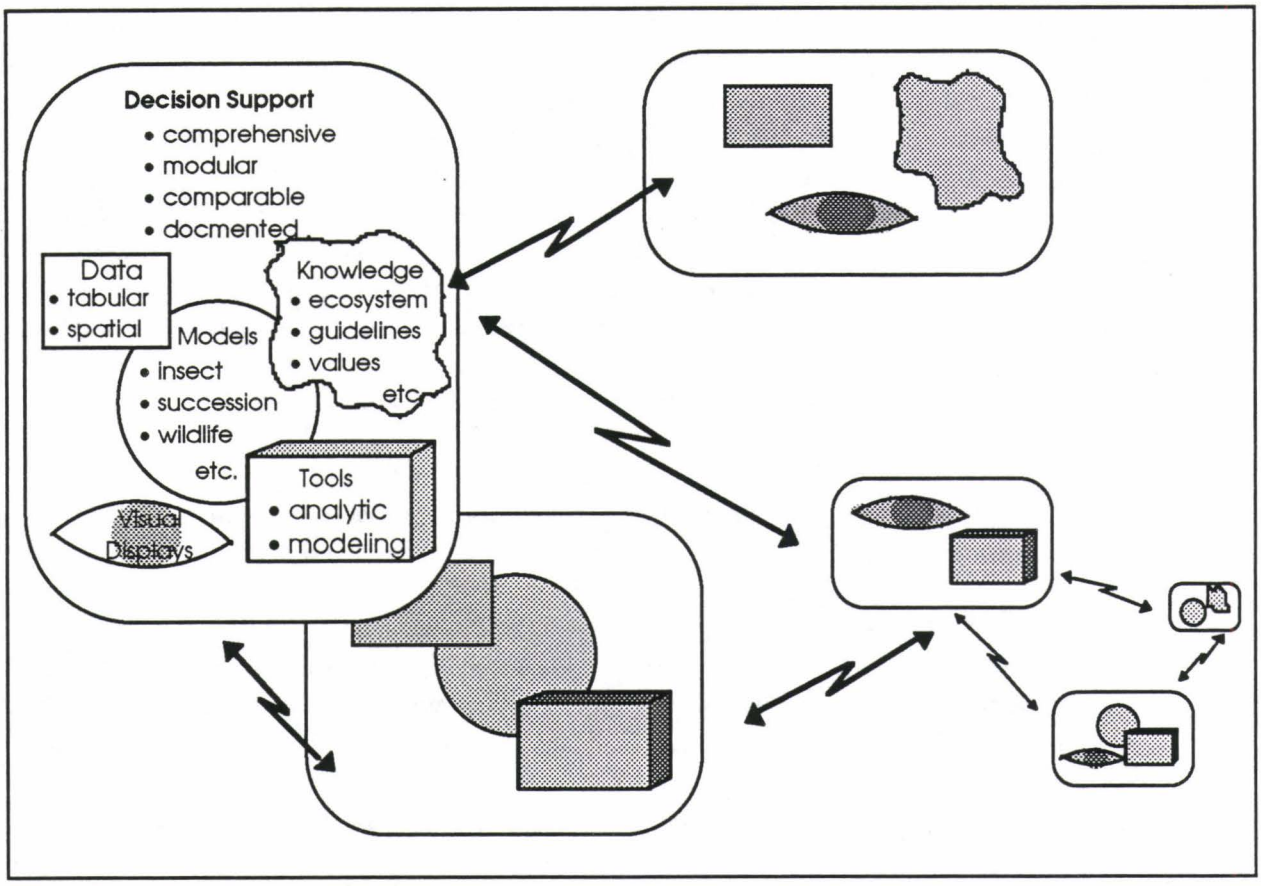

Figure 6.2: A conceptual overview of the technological components included in the DSS development strategy.

6.4 Strategy

It is not sufficient simply to develop or adapt technology to provide decision support tools for ecosystem management. The real value of such development efforts only comes with the adoption and application of the decision support systems by decision makers and their supporting resource analysts. The strategy for developing and applying decision support technologies thus incorporates four strategic initiatives. These initiatives are:

1. Co-ordination of the efforts of partners working on the development of tools and components which will be integrated into larger DSS frameworks and co-operation/participation with other groups working to establish the broad capabilities needed for ecosystem management.

2. Integration of the wide array of component tools (data acquisition and management tools, data visualization tools, valuation systems, and models of forest dynamics) into decision support system packages that provide decision makers with a range of tools that can be used efficiently in a consistent and coherent manner.

3. Development and adaptation of appropriate technologies and methods which support the integration of the various tools.

4. Establishment and enhancement of essential services to facilitate implementation (adoption/adaptation) of decisions support systems and provision of essential mechanisms for developers to learn and understand a) the needs of decision makers, b) capabilities and limitations of technologies, and c) the nature of factors which hinder implementation of decision-supporting technologies.

Recent advances in technology provide tremendous opportunities to leverage entirely new capabilities to meet the challenges of forest health assessment and ecosystem management. The maturity of "Open Systems" concepts and technologies provides new opportunities for resolving challenges of integration and provides technological solutions especially valuable to systems integration. Knowledge representation and knowledgebase tools provide unprecedented means of storing, expressing, and recording human knowledge and comprehension of ill-defined domains. Data modeling, database systems, and geographic information systems have evolved through application to business problems. Over the past decade, these systems have increasingly been applied to natural resource management and only now are providing a richness of data support and analytical capabilities which are imperative to environmental applications. Additionally, many federal agencies, private parties, and state organizations have dramatically increased their acquisition and use of these tools. This makes sharing of data and analytical tools much more feasible than in previous decades. New methods of navigating and sifting through complex and large scale data sets and text are now available which were undreamt of a few years ago. Computer processors provide real capabilities for serving multiple channels of communication (verbal, auditory, visual, tactile) in ways that were previously the stuff of only Asimov and Roddenbury fiction. These tools provide robust support for data exploration, and the expression of subtle and complex trends and relationships. Open access to data and information via information highways has greatly increased the skill of stakeholders using new technologies. Stakeholders' understanding of the limitations and caveats associated with data display and analysis has also increased.

6.5 Objectives

Co-ordination and Partnerships for decision support .

The job of developing a fully comprehensive decision support system for ecosystem management is realistically beyond the knowledge and experiences of the Methods Application Group, or any one group. Consequently, workshop participants saw the objective of developing an overall/generic structure primarily as a partnership initiative.

Decision support is essential to implementation of ecosystem management. The factors involved in the required decisions are simply too complex for any one person. In addition, because the planned decision process is to be shared and open, documentation of all the steps can be facilitated by a decision support system. The process is too comprehensive, affecting too many parts of the Forest Service to expect any single staff to do the development of an all-encompassing system. The development of any robust and comprehensive decision support system requires coordination and collaboration among many stakeholder groups (both within and external to the

Forest Service). This cooperation should be focused upon two primary urgent needs: 1) the description of a general conceptual model for decision support systems, and 2) the identification of indicators and criteria which facilitate forest health assessment and which are applied during the decision process for ecosystem management.

Integrate tools for consistent and coherent support of decisions

Data, values, and models about forest health need to be accessed and displayed through a unifying context which reflects the integrated nature of ecosystem management. This can be accomplished by delivering relevant information through integrated decision support system(s). Such systems would be honed to the context of ecoregions in order to maintain congruence of ecological processes and conditions. Many efficiencies of system development, support, training, and maintenance can be leveraged by sustaining a degree of commonality of technological linkages. These links may be manifested by technology pipelines between applications and/or similarities of design and coding which are essentially applications of open systems principles and methods. Although it can be wise to enable isolated applications (models, databases, image processing systems) to be packaged for direct use, it is equally important to provide a collection of technologies which is responsive to ecosystem analysis needs and maintains relevance and context to the entire decision cycle. This integration both maintains congruence with the holistic nature of ecosystem management and provides practical benefits by leveraging the efforts of many technology development teams in a complementary and coordinated manner.

Integration is the unifying forum for technologies supporting ecosystem management for forest health. Packaging, re-engineering, and technology transfer of the products from all technology areas in the Forest Health 2000 plan are important to the development of integrated decision support. The Forest Service needs to:

1. Assess appropriate level of integration of decision support tools,
2. Support synthesis of decision rationale and relevant information,
3. Agree upon methods of integration, and
4. Adapt existing systems to ecosystem management.

Forest Pest Management and Fire & Aviation systems staffs should initiate these efforts specifically for insect, pathogen, and fire components of ecosystems. They should collaborate with other specialists through the ecosystem management focus group and coordinate how this information can be integrated with decision support provided by the ecosystem management systems staff.

Develop New Technologies For Decision Support

Ecosystem management has introduced new needs for environmental assessment. Data about conditions must be looked at from fresh perspectives and synthesized with new criteria. Emerging technologies enable new analytical approaches. Landscape-level data and analysis methods are now crucial to forest health assessment and ecosystem management. Ecosystem management requires forest health specialists to provide data and explanations of conditions, processes, and implications of actions in contexts not previously tried. For example, the breadth and nature of what was

previously addressed in Forest Pest Management technical assistance evaluations radically changes with ecoregional and provincial-level forest health assessments. New approaches must be tried and evaluated and new guidelines agreed upon for these assessments. New levels of resolution of resource data need to be accessible and knowledge about the current understanding of ecological relationships needs to be delivered in credible ways. The ways that systems can be used during the decision process should be revised because the nature of decision criteria and indicators has greatly expanded from the prior commodity production era of forest management and because the array of stakeholders and means of stakeholder involvement have dramatically changed . This revision requires adaptation of existing systems to enhance analytical capabilities and the interaction with stakeholders. The activities in this suite of development projects are intended to respond to these new needs.

Facilitate Adoption and Implementation of Systems

The Forest Service needs to improve the effectiveness of technology transfer of software applications by increasing general awareness and skill in technology application scoping, development, dissemination, maintenance, and revision. This is especially true for technologies which are applied to any point in forest health analyses and the decision process. To improve system implementation we must improve the understanding and appreciation of the factors that inhibit adoption of the tools. This understanding of implementation needs to be shared among technology transfer units and informal development groups. Technology transfer units such as the Methods Application Group should provide essential services that would significantly increase the likelihood that valuable tools will be used and sustained.

6.6 Major Activities and Products

6.6.1 Coordination and partnerships for decision support

Task 1: Develop a generic decision model which supports decisions relevant to ecosystem management

This activity is the core for providing Decision Support to ecosystem management activities. A proposal to enhance existing decision support tools and protocols was initiated in 1993 by a group of WO-level systems development staffs, and research scientists (Coordinating Committee for Decision Support for Ecosystem Management). The Executive Committee for Ecosystem Management has recommended the ecosystem management staff organize and sponsor the development of a general conceptual model for decision support for ecosystem management. This Task Force Group recommends that the general conceptual model be developed over a 1-year period with dialogue among diverse stakeholders. This suite of activities should provide a model that can be adapted to individual situations with minimum effort. Understanding the explicit process by which ecosystem management decisions are or should be made is essential to being able to model that process. Considerable effort is needed to clarify the process. Development groups should share in responsibilities and coordinate their work with the Executive Committee for Ecosystem Management and with the Information Science and Technology staff through the ecosystem management focus group. The team working on this project must include users as co-developers in order to ensure a shared responsibility for the products and mutual commitment to related

activities. The overall cost will be shared among groups. The costs in this plan represent the estimated cost for the Methods Application Group to meaningfully participate in this work. The Methods Application Group should encourage participation by other staffs within State and Private Forestry. MAG has extensive experience in the development of integrated systems, models, data bases, and decision support systems for integrated resource management. The resulting skills and knowledge gained through their pilot implementations of systems and their kinship with relevant S&PF staffs is important to the success of this objective.

Activities and Products:

Stage 1: Define User Requirements and System Specifications

Convene a project team representative of users, scientist, and system developers. Identify preliminary decision factors, forest health indicators and relevant forest health assessment tools. Set sideboards for prototype development and scope implications of future systems development and implementation. Conduct series of focus group-type requirements analysis sessions.

Products:

- Report with details of requirements and specifications.

Stage 2: Develop Initial Prototype

Development of an early prototype will enable potential users to contribute their ideas to the process at a time when changes can be most easily incorporated. This prototype will be primarily a conceptual model that demonstrates how the system is expected to work when all the pieces are assembled. The prototype will aid dialogue and analysis among users and developers of the system. The prototype should clearly demonstrate a variety of ways forest health data can be depicted via display, modeling, and values representation.

Products:

- Software product to demonstrate capabilities of a decision support system.

Stage 3: Evaluate Prototype(s)

The purpose of prototyping is to enable a better final product through early iterations of trial and error. Extensive efforts need to be made to test whether the functions designed into the prototype actually address the needs of the managers and stakeholders. Detailed evaluation of the parts of the system which may either be lacking or present but unnecessary, will improve the function and utility of further revisions of the system. Conduct series of evaluative review sessions with formal review criteria and recording of feedback.

Products:

- Report with revised requirements and specifications.

Stage 4: Develop Advanced Prototype

Several versions of a prototype system are anticipated to be necessary. Each version will be successively more detailed and more functional. Each revision will also need to be evaluated by potential users among the managers and stakeholders, preferably through a pilot testing process.

MAG's role will be to assist design of the system, share expertise in pilot testing of relevant technology, and ensure forest health indicators, data, and models are featured components.

Products:

- Comprehensive system requirements suitable for development of core or shell for delivering diverse decision support tools in a consistent and cohesive context
- Prototype suitable to augment written specifications and maintained as a conversation or dialogue centerpiece
- Common understanding among development groups in the Forest Service, the research community, and IS&T of an approach for delivering shareable code and sustaining software relevant to forest health assessment and decision support for ecosystem management

Task 2: Identify indicators of forest health useful at multiple spatial scales and among areas

Appropriate indicators are needed to facilitate the evaluation of ecosystem conditions, and therefore determine the degree of success of ecosystem management. Common indices or indicators will facilitate communication among disciplines. Identification and specification of standard indicators, the methods by which they are generated or gathered, and the relationships among them have been identified as important tasks by all the task force working groups. The sponsorship of a forum which specifically includes a wide variety of interested parties is needed to generate discussion and identify which are the most important pieces of information to address. An important objective should be to provide needed guidance to persons developing tools to help make ecosystem management decisions. The forum (whether a specific project, a workshop or series of workshops) should include at a minimum representatives of diverse disciplines including forest health specialists, fire science specialists, ecologists, sociologists, and economists. The activities should be coordinated among Forest Service units as well as across relevant agencies, states, and tribal governments.

Activities and Products:

- Plan methods of accumulating and synthesizing known indicators
- Review and publish preliminary list of indicators
- Revise as understanding of indicators evolves
- Description of forest health indicators suitable for forest health assessment at the ecoregion level
- Plan of action for maintaining and revising indicator list among cooperators

6.6.2 Integrate and enhance tools for support of decisions

Task 1: Quantitative assessment of integration

Integration of software can be accomplished via many different approaches. Integrated systems can be loosely or tightly coupled. The approach and degree of integration has significant implications for long-term maintenance, training programs, and extension of systems. Application developers often hold strong opinions with regard to all these aspects of integration. Well funded independent development teams frequently do not feel motivated to coordinate work or design sharable system components. The benefits of integration are not uniformly understood or accepted. A rigorous assessment to quantify the values of integration is important. Quantified and credible

measures of costs and benefits of integration versus inconsistent and isolated applications can be very helpful. This information can help designers plan for a level of integration which best serves user needs and ensures efficient support of components.

Activities and Products:

- Report of assessment conducted over at least 2 study areas:
  a) Description of quantified costs and benefits of integration contrasted with isolated programs
  b) Description of enhanced or new capabilities experienced by users as a result of integration

Task 2: Develop protocols for integration and object libraries

Efficient and effective extraction, organization, and display of enormous quantities of information required for ecosystem management necessitates that conventions be established which enable module sharing and integration of disparate applications. New technologies and the continued evolution of higher orders of open systems capabilities are anticipated to rapidly progress over the coming decades. These systems empower autonomous applications development by individuals and small teams. The inventions from these efforts will undoubtedly have been in response to necessities of ecosystem assessment and as such hold promise for utility at other sites. In order to leverage the creativity and resources invested in these largely ad hoc development activities, conventions need to be established and documented which enable autonomous developers to design their products for potential integration. These conventions would be the basis for the design specifications for engineering object modules.

Object modules encapsulate specific low-level functions or serve as wrappers around existing software modules. For example, a useful object may be one which enables passing data from an insect population model to a vegetation growth model. A forest health program area should be the steward of a relevant object library. At a higher level this object library should be accessible to other development teams. A series of object libraries adhering to agreed upon conventions would form a virtual suite of object libraries accessible through worldwide networks. Forest health applications engineered as objects depicting defoliator behavior in Finland would thus be reusable in models of defoliator behavior in the U.S. and image display objects developed in the U.S. would be swappable with Russian system developers. In a more parochial sense, the same process would be feasible between the Forest Management Service Center and the Methods Application Group or between the Methods Application Group and the Southern Region Forest Health Protection staff.

Activities and Products:

- Description of protocol for interoperability among software systems
- Agreed upon conventions which development teams working on should follow and which are coordinated with other Forest Service developers and organizational guidelines.
- Object library

Task 3: Develop Approaches To Documenting Decision Rationale

Decisions for management of public lands are very complex. Interests of many parties must be considered and incorporated into resultant management activities. Many times the processes behind management decisions are not well documented, causing difficulty if such decisions are challenged. Previous decision support systems have not provided explicit tools for assisting the comparison of alternatives or support for recording decision criteria and interim judgements. Management science has a body of methods based on decision theory that is also pertinent to decision support for ecosystem management. These methods have been devised through application to other subject areas and need exploration and evaluation by Forest Service decision-makers and their supporting analysts. Beneficiaries will include the managers whose tasks may be made more efficient, the publics who will see a more open and well-documented decision making process, and the various components of the ecosystems that will receive better management. Creating a record of the decision and intermediate judgements which affect the choice of data and analytical methods is important also to monitoring results and providing information for adaptive management.

Activities and Products:

- Comprehensive literature and science search for relevant decision analysis
- Incorporation of 1 to 2 methods in prototype(s)
- Field test results from pilot ecosystem management areas
- Report with recommendations for future technology transfer and implementation at multiple spatial and temporal scales.

Task 4: Adapt existing systems

Several decision support systems and decision aids have been developed over the past 5 years. These systems largely reflect tightly bound domains (gypsy moth and southern pine beetle suppression project management) or respond to multiple use forest management as it has been implemented over the past decade (project-level planning and silvicultural actions). These tools should be sustained for immediate implementation and supported through their useful life (perhaps 5 years). They should be critically reviewed in order to determine the net value of adapting them to be responsive to ecosystem management principles and practices. Some of the systems have been designed to be adaptable to incorporate other agent (insect or pathogen) information in the context of the application domain (suppression program). For example GypsES may be adaptable to supporting the decision cycle for suppression of spruce budworm or SPBEX may be adapted as a knowledge base for other insects or pathogens.

Prudent adaptation and implementation of existing systems is important to capturing the benefits of the investments made in technology development and following through with the complete technology transfer cycle. The nature of this technology adaptation, transfer, and sustained commitment to the products, requires a critical mass of expertise and technological capabilities which is rarely available at the originating units. As a short-term effort, existing systems should be adjusted in minor ways for delivery through a more comprehensive information system framework. Longer-term objectives should include re-engineering specific components of existing systems to be modular and enable some common capabilities such as screen-based digitizing and complex query processing to be satisfied through a library of sharable functions (such

as object programs). This re-engineering would focus on features which are common to many resource management applications. Re-engineering should be done for especially valuable applications in order to reduce code maintenance and to more easily integrate system components into future systems.

Products and Activities:

- Assessment of DSSs which hold obvious potential for ecosystem management or new geographic areas of application.
- Re-engineering of systems as appropriate, and packaging for technology transfer and adoption.
- Training and technology maintenance for life of system.

6.6.3 Develop new technologies for decision support of ecosystem management

Task 1: Establish a Landscape-Level Information Needs Assessment Process

Ecosystem management requires forest health assessments be conducted at the landscape level. Forest health specialists are being asked to contribute information about forest health change agents such as insects, pathogens, and fire. Although some regions have begun to conduct forest health assessments, the methods are not fully mature and have not been applied to enough areas to ascertain what elements of landscape-level information should be considered. Conducting landscape-level assessments is well beyond previous technical assistance evaluations. Forest health specialists need to know methods and measures of forest health pertinent to their role in ecosystem management. Forest health specialists also need to understand which characteristics and relationships between agents are unique to certain ecoregions. These specialists need automated tools to assist in data collection, management, and synthesis for landscape-level forest health assessments.

This activity requires that a review and examination of ongoing forest health assessments be conducted. Forest health specialists and research scientists will be consulted to determine appropriate methods and data for a target or initial ecoregion. Technology tools which assist the assessment process will be prototyped. Data and relationships which are common across ecoregions will be identified and will be the core of the process. Data and relationships among and between forest health agents and their role in ecological processes which are not universal will also be highlighted. These will require forest health specialists to use unique and novel approaches beyond the scope of the "generalized" process scheme. Technology transfer sessions will be used to train forest health specialists and to share experiences.

Activities and Products:

- Report of landscape level forest health assessment methods utilized to date.
- Critical review of methods and identification of commonalities and distinctive assessment needs.
- Prototype technology applications or utilities which assist forest health specialists in conducting landscape-level assessments of forest health.

- At least 2 workshops for technology and information transfer to and between forest health specialists.

Task 2. Develop Knowledge Bases For Hazard And Risk

Much is known about assessing hazard and risk for forest change agents at the stand level. Less is known about determining hazard and risk at broader scales. Additional knowledge is "hidden" in many research studies and literature. Delivery of this knowledge to district and forest resource analysts is crucial to assessing forest health efficiently. Knowledge-bases can be a very effective means of storing and providing access to a wide variety of information, especially when implemented in a hypermedia environment. Creation of knowledge-bases will undoubtedly illuminate gaps in data and knowledge. These gaps will be important drivers for research studies. The creation of knowledge-bases will in turn assist research scientists to better understand the nature of data and knowledge required by resource analysts.

This activity involves the development of a series of knowledge-bases for a single ecoregion. Templates or utilities for developing knowledge bases will be developed and transferred via training sessions. These tools will be useful for the future development of knowledge-bases for additional ecoregions for which the development of knowledge-bases is beyond the scope of this activity.

Activities and Products:

- Review and report of data and methods relevant to forest health
- Toolkit for building knowledge bases for ecoregions.
- Complete series of forest health knowledge bases for a single ecoregion.
- Re-use knowledgebase toolkit as template for creating knowledge bases for many other ecoregions (long-term).

Task 3: Extend Existing Operable Systems

Useful decision support technologies exist, but are not available to meet all forest health needs. Extension and integration of existing independent systems can help provide useful interim solutions to forest health management problems while new systems are being developed. Considerable effort, time, and money has been invested in systems that now have limited applicability. Many of these systems can be adapted to provide more functionality to help manage forest health problems that they now address only in part. Others may be adapted to address parallel tasks, such as suppression or prevention, but for different ecosystems. These adaptations will allow previous development efforts to be modified to fit the generic model for decision support system for ecosystem management and therefore reduce resources needed to implement some parts of future systems.

Activities and Products:

- Identify candidate systems for adaptation.
- Develop new application(s) or extensions.
- Report on options, costs, and benefits for different candidate applications.
- Completed new applications.

Task 4: Develop an automated landscape-pattern recognition system

Landscape-level patterns are important for ecosystem management because so many of the processes that need to be monitored and managed occur at the landscape level. For example, the distribution of high forest cover, young forest, and cleared land plays a key role in wildlife habitat and visual quality of a landscape. Automated image processing to identify patterns and detect changes can significantly improve the information available to support decisions.

The capability to identify patterns and distinguish among different patterns through time will assist in identification of defoliated areas of forest, development activity, and habitat loss or gain. Chief beneficiaries of such technology would be land managers, pest managers, and scientists.

Activities and Products:

- Evaluate data available for applications development.
- Develop analysis process with images of known landscapes.
- Test procedures on multiple landscape types.
- Produce software application.
- Software to process images of landscapes and recognize patterns

6.6.4 Facilitate Adoption and Implementation of Systems

Task 1: Establish Training Resource Center

The Training Resource Center would allow for the provision and assistance in a wide variety of services. The Training Resource Center would be a new venture for FPM that builds upon existing strengths. This resource center would allow for consistency and standards in development, training, documentation, tutorials, workshops and support for decision support system(s). The standardization of products would allow for easier acceptance by users, increase usage, and help complete the technology transfer process for decision support system(s). The cost per user for decision support system(s) would be substantially lower in the long range, due to increased numbers of DSS users.

This Resource Center would facilitate the use of FPM developed decision support system(s) by:

- developing training materials for the decision support system.
- documentation policy and standards for effective user manuals.
- preparation of user tutorials on the decision support system.
- presentation of decision support system(s) and training workshop(s) should be provided.

Support and Maintenance of Decision Support System(s) and Tools. This would include the following areas:

- aerial videography
- modeling
- hazard rating

- knowledge bases
- development of efficient data capture and interpretation
- hotline support
- software quality assurance
- enhancement of new technology
- interaction between developers through biennial workshops.

Task 2: Develop a clearinghouse for decision support systems and related tools.

We recommend the Methods Application Group provide clearing house services in order to communicate and market decision support products relevant to forest health, especially change agents and their roles in ecosystems. This would enable all users to have access to knowledge and data of available products. The scheme of the Training Center would be to provide information by newsletters, site visits showing demonstrations, libraries of information, and technology support of products available throughout FPM. This service would benefit all by improving coordination and visibility of products, as well as increase use of products and supply an efficient source of knowledge, data, information and tools.

Activities and Products:

- Newsletters could be distributed electronically through Project 615 equipment on a quarterly basis.
- Demonstrations of prototypes and products.
- Library of decision support systems and documentation in order to ensure there is a recognized and reliable source of current versions.
- A library of currently available baseline data and coverages available throughout Forest Pest Management and other agencies. This would enable the user to access forest health related data sets.
- Evaluation of the decision support system related to ecosystem management. This evaluation process would ensure that the product and documentation adhered to Forest Service policy. Documentation standards would need to be established and followed. The evaluation could insure the applicability between regions of the decision support product.

Task 3: Develop Protocols For Pilot Tests Of Decision Support Systems

Many DSS tools have been abandoned in the field because of inadequate understanding of their target operating environment (the realities of system management, training availability, facilities and level of proficiency of users). A better process for identifying and removing roadblocks to the use of existing tools will increase the chances for adaptation of existing and future tools. Each developed tool may go through one or more cycles of pilot testing until it is abandoned or adopted operationally. Chief beneficiaries of the proposed work will be managers who are able to adopt the technological aids that have enhanced usefulness because of the improved pilot testing procedures. Also benefiting are the developers and technology transfer specialists whose work is more readily accepted in the field.

Activities and Products:

- Consolidate current information on pilot testing
- Draft Protocols
- Review protocols
- Test protocols with new pilot test site
- Review and publish protocols
- Protocol and procedures for installation, monitoring, and evaluation of pilot tests for technology development projects

6.7 Resource Requirements

The preliminary estimates of the resources required for the implementation of the activities outlined by the Decision Support System Group are summarized in Table 6.1.

Table 6.1: Resource requirements for the Decision Support Group.

Major Activities and Products	Cost (1,000)	Duration (years)
Coordination and partnerships	780	5
Integrate tools for consistent and coherent support of decisions	2,500	5
Develop new technologies for decision support	2,610	5
Facilitate adoption and implementation of decision support systems	3,000	5
Total	8,890	

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Appendix II: Resource Requirement Summaries

Value Determination

Activity	total $	95$	96$	97$	98$	99$
1 Value determination						
1.1 Determine relevant held values, stakeholders, indicators	*750.0*	400.0	350.0			
1.2 Develop methods to identify and track values, stakeholders, and indicators	*600.0*	50.0	100.0	200.0	150.0	100.0
1.3 Develop methods to determine & measure assigned values for alternatives	*950.0*	200.0	100.0	250.0	200.0	200.0
1.4 Develop Value Referencing System (VRS)	*1,125.0*		225.0	300.0	300.0	300.0
1.5 Develop system to structure & display assigned value sets in multi-dimensions	*1,075.0*	100.0	225.0	250.0	250.0	250.0
	4,500.0	*750.0*	*1,000.0*	*1,000.0*	*900.0*	*850.0*
Grand Total	4,500.0	750.0	1,000.0	1,000.0	900.0	850.0

Data and Information Needs

Activity	total $	95$	96$	97$	98$	99$
1 Standardize FPM data collection & management procedures						
1.1 Information needs assessment	*290.0*	150.0	90.0	50.0		
1.2 GIS Database framework	*15.0*		15.0			
1.3 Develop & maintain FPM data and process models	*143.0*	50.0	20.0	22.0	24.0	27.0
1.4 Develop links to external data sources	*70.0*	20.0	20.0	10.0	10.0	10.0
1.5 Coordinate with other staffs and agencies	*80.0*	20.0	20.0	20.0	10.0	10.0
	598.0	*240.0*	*165.0*	*102.0*	*44.0*	*47.0*
2 Vegetation cover and change detection						
2.1 Coordination with other agencies	*100.0*	20.0	20.0	20.0	20.0	20.0
2.2 Technology assessment	*350.0*	50.0	60.0	70.0	80.0	90.0
2.3 Spatial, temporal, spectoral signature	*700.0*	100.0	120.0	140.0	160.0	180.0
2.4 Technology transfer	*250.0*	30.0	40.0	50.0	60.0	70.0
	1,400.0	200.0	240.0	280.0	320.0	360.0
3 Automate anthropogenic and natural disturbance detection						
3.1 Identify characteristice of ecounits w/rit stressors/ what makes the ...	*30.0*	30.0				
3.2 Evaluate existing data collection techniques/tech. assessment	*75.0*	75.0				
3.3 Technology/techniques development and testing	*440.0*		120.0	220.0	100.0	
3.4 Standardized causal agent and change detection process	*120.0*				120.0	
3.5 Augument veg. layr with change by cause	*550.0*	80.0	110.0	115.0	120.0	125.0
3.6 Coordination and standardization with states, other agencies etc.	*155.0*	25.0	28.0	31.0	34.0	37.0
	1,370.0	210.0	258.0	366.0	374.0	162.0
4 Procedures & methods for integrating disturbances						
4.1 Pilot study	*200.0*	90.0	100.0	10.0		
4.2 Pilot study	*270.0*			100.0	120.0	50.0
4.3 Synthesis and reporting	*400.0*		50.0	50.0	150.0	150.0
	870.0	*90.0*	*150.0*	*160.0*	*270.0*	*200.0*
Grand Total	4,238.0	740.0	813.0	908.0	1,008.0	769.0

Analysis and Modelling

Activity	*total $*	95$	96$	97$	98$	99$
1 Models for choosing desired future conditions						
1.1 Select problem indicators, processes, bound system	*0.0*	0.0	0.0	0.0	0.0	0.0
1.2 Identify indicators affecting processes	*0.0*	0.0	0.0	0.0	0.0	0.0
1.3 Review of known processes, available data & tools	*0.0*	0.0	0.0	0.0	0.0	0.0
1.4 Build missing tools	*0.0*	0.0	0.0	0.0	0.0	0.0
1.5 Beta testing, validation	*0.0*	0.0	0.0	0.0	0.0	0.0
1.6 Process development, evaluation, & implementation	*0.0*	0.0	0.0	0.0	0.0	0.0
	1,450.0	**540.0**	**280.0**	**280.0**	**280.0**	**70.0**
2 Model reviews and user support services						
2.1 Review of MAG supported models	*180.0*	180.0	0.0	0.0	0.0	0.0
2.2 Beta testing and model modifications	*400.0*	80.0	80.0	80.0	80.0	80.0
2.3 Transfer & training	*225.0*	45.0	45.0	45.0	45.0	45.0
2.4 Maintenance	*920.0*	130.0	130.0	220.0	220.0	220.0
2.5 Invalidate & monitor new data	*390.0*	50.0	85.0	85.0	85.0	85.0
2.6 PTIPS data base administration	*460.0*	120.0	85.0	85.0	85.0	85.0
2.7 Suppose frameword	*300.0*	150.0	150.0	0.0	0.0	0.0
	2,875.0	**755.0**	**575.0**	**515.0**	**515.0**	**515.0**
3 Lanscape-level multi-agent models						
3.1 Combined models of single agents	380.0	270.0	110.0	0.0	0.0	0.0
3.2 Select prototype ecosystem for multi-agent model	*85.0*	0.0	85.0	0.0	0.0	0.0
3.3 Identify indicators affecting processes	*85.0*	0.0	85.0	0.0	0.0	0.0
3.4 Build missing tools	*1,350.0*	0.0	190.0	580.0	580.0	0.0
3.5 Beta testing, validations	*410.0*	0.0	0.0	0.0	0.0	410.0
	1,930.0	**0.0**	**360.0**	**580.0**	580.0	410.0
Grand Total	6,535.0	1,565.0	1,325.0	1,375.0	1,375.0	995.0

Information Display

Activity	*total $*	95$	96$	97$	98$	99$
1 "ForestViewer" shell						
1.1. Define concept	*23.0*	15.0	8.0			
1.2. Implementation plan	*7.0*	2.0	5.0			
1.3. Contracting	*10.0*	5.0	5.0			
1.4. Software development	*247.0*	75.0	82.0	90.0		
1.5. Technical support	*35.0*		5.0	15.0	15.0	
	322.0	**97.0**	**105.0**	**105.0**	**15.0**	**0.0**
2 SmartForest Module						
2.1. Define concept	*47.0*	15.0	8.0	8.0	8.0	8.0
2.2. Implementation plan	*22.0*	2.0	5.0	5.0	5.0	5.0
2.3. Contracting	*5.0*	5.0	0.0	0.0	0.0	0.0
2.4. Software development	*1,000.0*	150.0	175.0	200.0	225.0	250.0
2.5. Technical support	*205.0*	35.0	35.0	40.0	45.0	50.0
2.6. Data acquisition	*20.0*	20.0				
	1,299.0	**227.0**	**223.0**	**253.0**	**283.0**	**313.0**
3 Scenario Sketchpad						
3.1. Define concept	*47.0*	15.0	8.0	8.0	8.0	8.0
3.2. Implementation plan	*27.0*	7.0	5.0	5.0	5.0	5.0
3.3. Contracting	*5.0*	5.0	0.0	0.0	0.0	0.0
3.4. Software development	*300.0*	50.0	55.0	60.0	65.0	70.0
3.5. Technical support	*35.0*	5.0	6.0	7.0	8.0	9.0
3.6. Data acquisition	*25.0*	25.0				
	439.0	**107.0**	**74.0**	**80.0**	**86.0**	**92.0**
4 ImageNet						
4.1. Define concept	*23.0*	15.0	8.0			
4.2. Implementation plan	*12.0*	7.0	5.0			
4.3. Contracting	*5.0*	5.0	0.0			
4.4. Software development	*105.0*	50.0	55.0			
4.5. Technical support	*135.0*	5.0	25.0	30.0	35.0	40.0
4.6. Data acquisition	*5.0*	5.0				
	285.0	**87.0**	**93.0**	**30.0**	**35.0**	**40.0**
5 Image Evaluation						
5.1. Define concept	*15.0*	15.0				
5.2. Implementation plan	*37.0*	2.0	10.0	10.0	15.0	
5.3. Contracting	*2.0*	2.0				
5.4. Conduct study	*270.0*	60.0	65.0	70.0	75.0	
5.5. Conduct study	*285.0*	100.0	110.0	75.0		
	609.0	**179.0**	**185.0**	**155.0**	**90.0**	**0.0**
6 Forest Futures Educational Software						
6.1. Define concept	*60.0*			60.0	0.0	0.0
6.2. Implementation plan	*15.0*			15.0	0.0	
6.3. Contracting	*15.0*			15.0		
	90.0	***0.0***	***0.0***	***90.0***	***0.0***	***0.0***
Grand Total	3,044.0	697.0	680.0	713.0	509.0	445.0

Decision Support Systems

Activity	*total $*	95$	96$	97$	98$	99$
1 Coordination & Partnerships for DSS						
1.1 DSS technology development/adapation	*220.0*	60.0	40.0	40.0	40.0	40.0
1.2 Forest health indicators	*260.0*	60.0	80.0	40.0	40.0	40.0
	480.0	***120.0***	***120.0***	***80.0***	***80.0***	***80.0***
2 Integrate Tools						
2.1 Value assessment of system integration	*258.0*	27.0	88.0	102.0	41.0	0.0
2.2 Protocol for interoperability of DSS components	*820.0*	115.0	155.0	195.0	177.5	177.5
2.3 Explore approaches to doc. decision rationale	*384.0*	41.0	74.0	94.0	94.0	81.0
2.4 Modular adaptation of existing tools	*750.0*	97.5	97.5	185.0	185.0	185.0
	2,212.0	***280.5***	***414.5***	***576.0***	***497.5***	***443.5***
3 Develop New Technologies						
3.1 Landscape level INA	*535.0*	95.0	110.0	110.0	110.0	110.0
3.2 Coord. development hazard/risk - knowledge bases	*445.0*	77.5	117.5	155.0	95.0	0.0
3.3 New automated pattern recog. tech.	*207.5*	42.5	42.5	37.5	42.5	42.5
	1,187.5	***215.0***	***270.0***	***302.5***	***247.5***	***152.5***
4 Facilitate Adoption						
4.1 Training Research Center	*1,950.0*	460.0	372.5	372.5	372.5	372.5
4.2 Develop a clearinghouse for DSS	*1,012.5*	232.5	195.0	195.0	195.0	195.0
4.3 Develop protocols for pilot testing	*184.0*	41.0	85.0	58.0	0.0	0.0
4.4 Adapt existing	*452.0*	24.0	214.0	214.0	0.0	0.0
	3,598.5	***757.5***	***866.5***	***839.5***	***567.5***	***567.5***
Grand Total	**7,478.0**	**1,373.0**	**1,671.0**	**1,798.0**	**1,392.5**	**1,243.5**